MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Achievements of Mechanical Engineers

Single-turbine generators capable of producing 208,000 kw.

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AUGUST 1927

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

By the way, how did that big oxwelded kiln stand up?★

MORE THAN three years ago a large rotary kiln was built by oxwelding. It was a notable piece of welding construction — 8 ft. in diameter and 125 ft. long, made of ⅝-in. steel plate. At the time it was thought remarkable that the tolerance of ⅝-in. should be so easily met with welded construction.

Now, after three years of operation, it is fair to ask, is it still working satisfactorily?

The answer is—Yes.

It is one of a battery of three kilns used in lime burning. The other two are riveted. The oxwelded kiln is dust-tight and running true on its trunions. As an operating unit it is beyond criticism.

Some convincing tests were made on these kilns with an extensometer. They showed beyond question that the oxwelded kiln was in better shape after two and a half years than the riveted ones. "Slippage" at riveted joints was found to be two and a third times as great as the stresses warranted. Stresses calculated from these measurements showed that the welded kiln could have been made of ½-in. plate instead of ⅝-in.; whereas a riveted kiln of the lighter plate would have shaken itself to pieces. This would mean a saving of eight tons of steel and a corresponding lowering of bending, handling, and erecting costs for oxwelding.

Recent oxwelding developments have made it possible to weld much heavier plate with no greater tolerance limits.

The experience with this pioneer kiln has started a revolution in tank construction, thanks to the strength and ruggedness of the welded joints. And there are today some of the oldest and most reliable manufacturers of tank construction engaged in this class of work.

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation

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37 PLANTS · 30 East 42d Street · 107 WAREHOUSES

LINDE OXYGEN

★No. 8 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled: "Engineering and Management Phases of Oxwelded Construction."

Mechanical Engineering

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H. F. Scott


W. Runge


O. B. Zimmerman


L. B. McMillan


C. J. Fechheimer


P. F. Walker

Contributors to This Issue

O. B. Zimmerman was graduated at the University of Wisconsin in 1896 with the degree of B.S., receiving his M.E. in 1900 and the honorary degree of Sc.D. from Pennsylvania Military College in 1919. For five years he served on the engineering faculty of the University of Wisconsin. Since 1905 he has been continuously in practical engineering work largely related to internal-combustion-engine tractor development and related problems in farm machinery, both here and abroad.

* * * * *

W. N. Polakov, president of Walter N. Polakov & Co., Inc., New York, N. Y., received his education at the Moscow Royal Institute of Technology, Dresden University, and the University of Moscow. Mr. Polakov became associated with the American Locomotive Co. as power-plant betterment engineer in 1907, remaining with them for two years. He next served for a year as expert consulting engineer on the Board of Estimate and Apportionment, City of New York. Following this he was associated with Harrington Emerson, H. L. Gantt, and Day & Zimmermann in installing scientific management in public utilities. He established himself as a consulting engineer in New York in 1915, specializing in management problems, and incorporated in 1919 as the Walter N. Polakov & Co., Inc. Mr. Polakov is also president of the American Engineering & Sales Corporation with headquarters in Washington, D. C.

* * * * *

H. F. Scott was graduated from the Massachusetts Institute of Technology in 1898, with degree of B.S. in mechanical engineering. He is plant engineer for the Dennison Manufacturing Co., Framingham, Mass., and since 1898 has been connected with the development and design of special machinery used in the manufacture of paper products by that company.

* * * * *

L. K. Sillcox, general superintendent of motive power of the Chicago, Milwaukee & St. Paul Railway Co., was graduated at the Polytechnic School of the University of Brussels, Belgium, in 1903. He has since been connected with the New York Central and Hudson River Railroad, the McSherry Manufacturing Co., Middletown, Ohio, the Canadian Car & Foundry Co., Montreal, Canada, the Canadian Northern Railway System, Toronto, and the Illinois Central Railroad, Chicago, Ill. In 1918 he became master car builder for the Chicago, Milwaukee & St. Paul Railway Co.

* * * * *

C. J. Fechheimer, research engineer in the power-engineering department, Westinghouse Electric & Manufacturing Co., received his B.S. in E.E. from Purdue in 1904 and his M.E. from Cornell in 1905. From that year until 1910 he was employed in the engineering department of the Allis-Chalmers Co., and then for five years was connected with the Crocker-Wheeler Co. Since 1914 he has been associated with his present concern.

* * * * *

W. Runge, associated with the International Engineering Corporation, New York, received his B.S. from Colgate in 1906 and his Ph.D. from the University of Goettingen, Germany, in 1909. From 1910 to 1917 he was connected with the E. I. Du Pont de Nemours & Co., resigning to become chief chemist of the International Coal Products Corporation and later President. He was for two years engaged as a consulting engineer in chemical work before taking his present position.

* * * * *

F. J. Hoxie, associated since 1903 as insurance inspector with the Factory Mutual Fire Insurance Companies, Boston, Mass., was graduated at the Massachusetts Institute of Technology in 1892, receiving his B.S. in electrical engineering. He was for a while in business for himself as an electrical contractor before becoming associated with his present concern. His work for the past ten or fifteen years has consisted mostly of research studies on fire and explosion hazards and in this work special laboratory methods and appliances have been used, notable among them being the houses for dust explosions, the largest of which has a cubic content of 15,000 cu. ft.


F. J. Hoxie


W. N. Polakov

* * * * *

L. A. Hartley, who writes on Industrial Problems or Difficulties, a True Basis for the Development of Foremen, is director of education of the National Founders Association, Chicago, Ill.

* * * * *

F. W. Thomas, who writes on Railway Apprenticeship in a National Apprenticeship Plan, is supervisor of apprentices of the Atchison, Topeka & Santa Fe Railway Co.

* * * * *

Perley F. Walker, Dean of the School of Engineering, University of Kansas, received degrees of B.M.E. and M.E. from the University of Maine in 1896 and 1900 and the degree of M.M.E. from Cornell University in 1901. From 1902 to 1905 he served on the faculty of the University of Maine as professor of mechanical engineering, then resigning to accept a similar professorship with the University of Kansas. In 1913 he was appointed Dean. He is also engaged in consulting work on petroleum and power-engineering lines, reporting on industrial development possibilities. During the War he served in the Engineers Corps, holding the rank of Colonel.

* * * * *

L. B. McMillan, chief engineer of Johns-Manville, Inc., New York, N. Y., was graduated from the Texas A. & M. College in 1911 with the degree of B.S., later receiving his M.E., Ch.E., and M.S. after post-graduate work which he took at both Texas and the University of Wisconsin. He was awarded a Fellowship at Wisconsin for 1913–14 and then was employed there for two years as instructor in steam and gas engineering. He became connected with the Johns-Manville Corporation in 1916.

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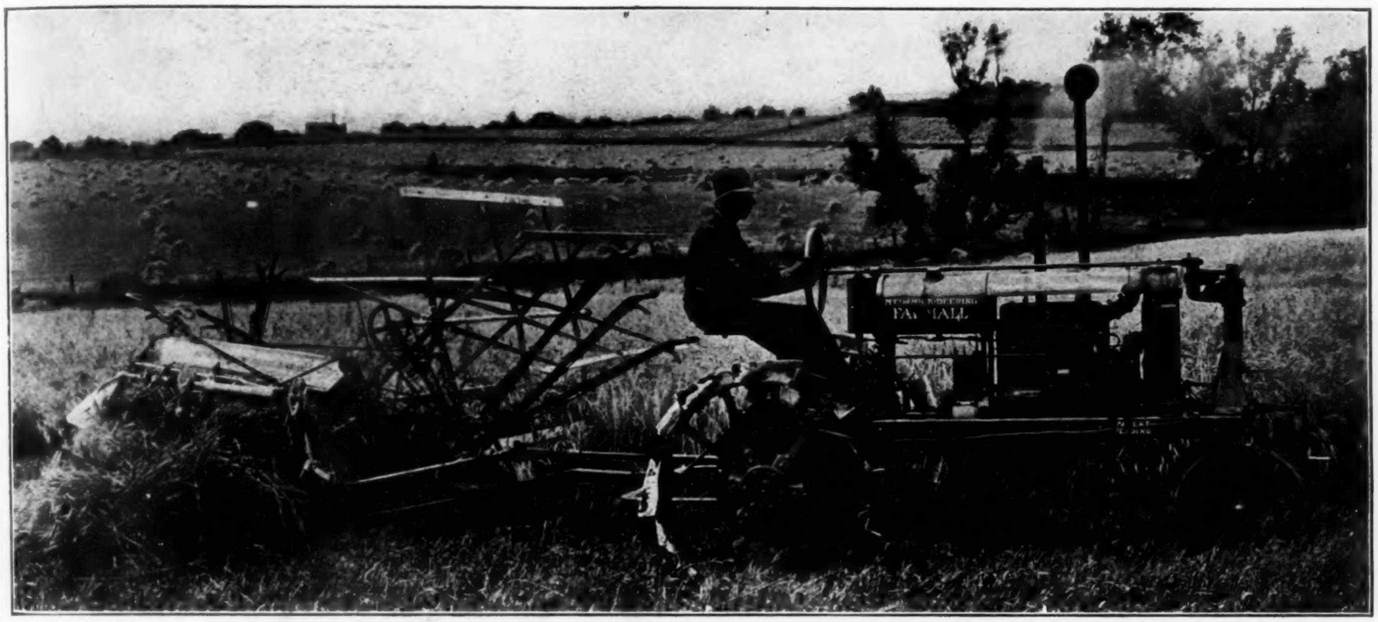

FIG. 1 ALL-PURPOSE TRACTOR AND 10-FT. BINDER
(Will operate in the hottest of weather—24 hours a day at the rate of 4 acres per hour. Note the binder receives the power from the tractor through the power take-off shaft.)

The Application of Machinery to Agriculture

An Outline of Some of the Problems Involved in the Mechanization of Agriculture, with Which Engineers in Other Fields of Industry May Be Somewhat Unfamiliar

BY O. B. ZIMMERMAN,[1] CHICAGO, ILL.

THE title of this paper, The Application of Machinery to Agriculture, furnishes the explanation of how and why it is that the United States outranks the world in agricultural production per man; of why and how, with so small a part of the world's population, it produces so large a part of the world's supply of foodstuffs.

These same six words also help to explain how the United States has achieved and maintains its conspicuous world supremacy in practically all departments of manufacturing industry. A generally accepted estimate shows that if we were compelled to feed and clothe our own population—to say nothing of our vast exports of farm products—by the means and methods available three-quarters of a century ago it would require the presence and labor on our farms of 20 million more workers than are now so employed. In other words, the application of machinery to agriculture sets free from the soil 20 million workers for the service of manufacturing and other industry.

Broadly and practically speaking, the mechanization of agriculture is a new art. It is difficult now to realize that eighty years ago there were virtually no farm-implement factories. Making the few and simple tools that agriculture then knew was the job of the blacksmith, the wheelwright, and the farmer himself; even the farm wagon was often home-made. The contrast between then and now is both striking and significant. Today there is hardly a town too small to have its farm-implement dealer, distributing the widely varied, highly specialized, and constantly improving tools and machines whose range provides some means of dealing effectively with every phase of farm operation.

Again, speaking broadly, the mechanization of agriculture is now passing into its third major phase. First was the period of hand farming that began when, before the dawn of history, the first man scratched the soil with a sharpened stick and planted the seed of some edible wild plant—a period that lasted until the advent of the reaper and the steel plow about the middle of the last century. After that came the period of farming with animal power, and with a rapidly developing line of machines to cover all operations from the making of the seed bed to the harvesting of the crop. Now we are at the beginning of the age of mechanical power farming; we are witnessing today a change almost as revolutionary as that which marked the transition from hand to animal power on the farm.

The effects of these two great advances in agriculture have often been measured in economic and sociological terms. The purpose of this paper is to deal with them rather with a view to outlining some of the mechanical problems involved which may be somewhat unfamiliar to engineers engaged in other fields of industry.

Agricultural machinery may be grouped for the purposes of this paper as follows:

Stationary—Where the machine setting may be considered reasonably permanent.

Portable—Where there are several more or less temporary uses which warrant set-ups for the different jobs.

[1] Assistant to Manager, Experimental and Engineering Department, International Harvester Company. Mem. A.S.M.E.

Presented at the Kansas City Regional Meeting of the A.S.M.E., Kansas City, Mo., April 4 to 6, 1927.

Mobile—Or those machines whose main function is performed while they are in motion.

Many points of value might be brought out in a review of the stationary and portable agricultural machines, but the class of mobile units involves so many more real and distinctive engineering problems and successes that our attention will be centered on it in this discussion.

each successful and economically valuable machine. Every successful designer must know these requirements and have them so definitely in mind that they will be reflected in his solutions, whether they be simple and rugged or intricate and delicate. These dominating operations may be classified as follows:

1 Development of power for belt work, transportation, and for draft

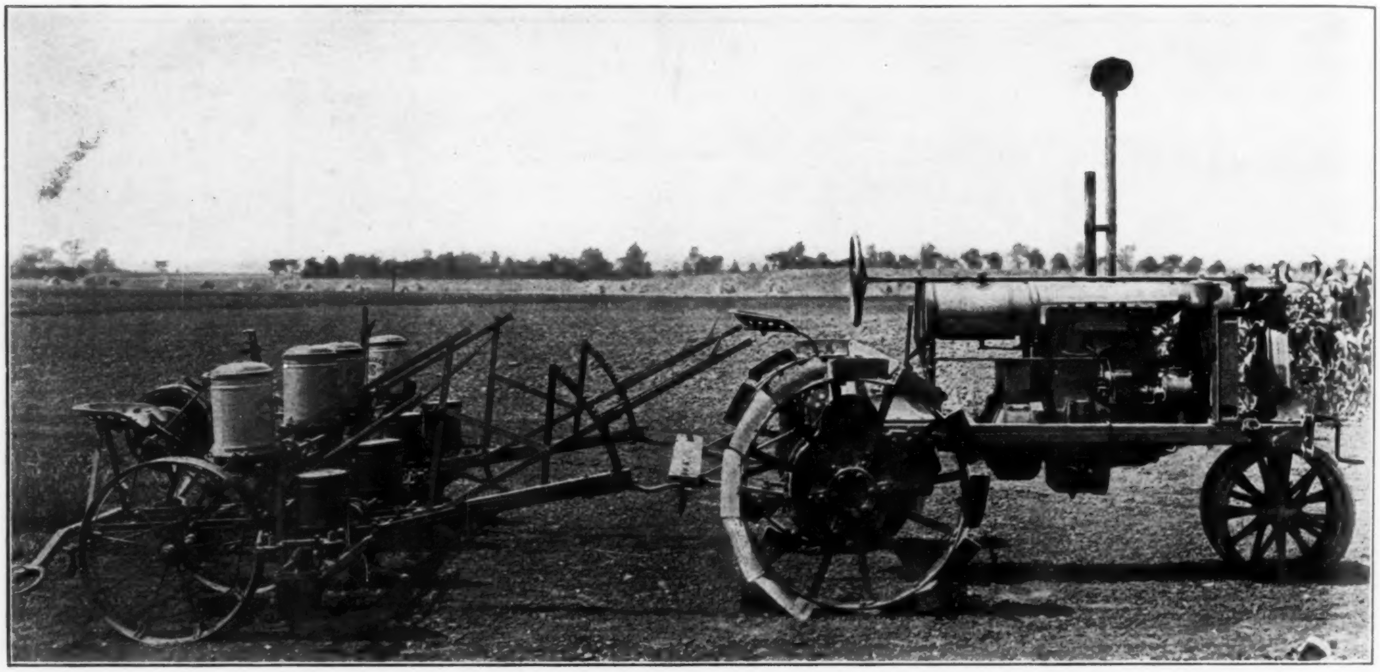

FIG. 2 THE FARMALL AND A FOUR-ROW CORN PLANTER

(Machined to drop accurately four hills of an equal number of kernels with varying corn sizes at the rate of 50 acres a day.)

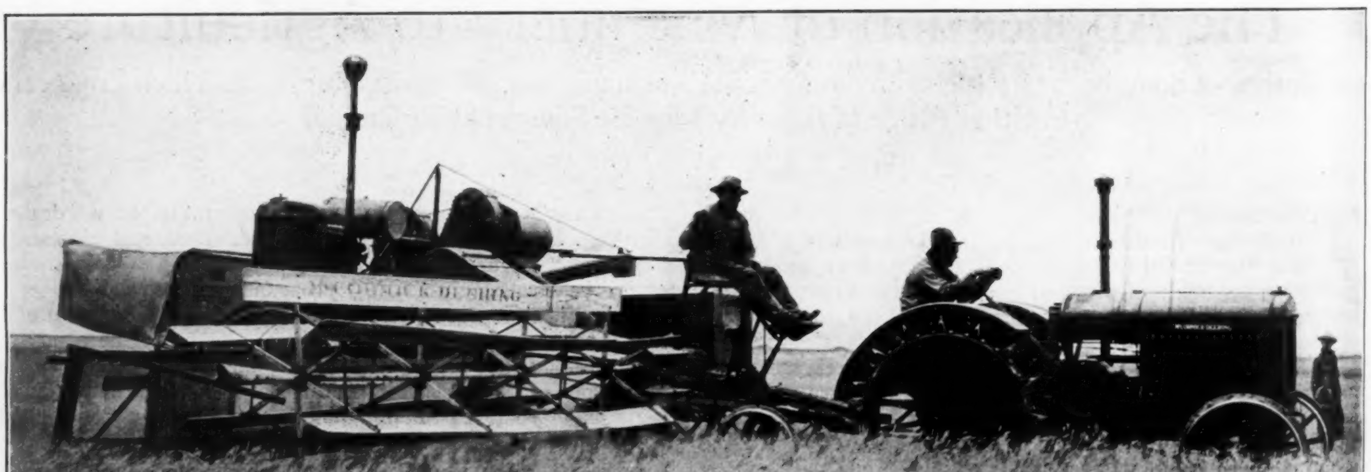

FIG. 3 THE HARVESTER-THRESHER

(It has brought to the grower of the West, modern methods which compare favorably with the most up-to-date systems in manufacturing. After three years of test under the most trying conditions, grain growers in the central states may now take advantage of harvesting and threshing at one time with one machine. Reduction in time and labor, as well as other costs, makes it possible to harvest and thresh a bushel of grain at a cost of from three to five cents, as compared with 25 and 50 cents by the old two-machine method.)

Interesting—and we may even say at times, spectacular—mobile applications are those devoted to row-crop, grain-field, root-crop, and orchard areas, where the machine must go to the work, that is, to the crop, to perform its service. In this feature we see a marked contrast with most industrial operations, where the material is usually brought to the machine rather than the machine to the material; and thus mobile requirements stand out prominently in every detail of the design of this large group of machines.

For the moment, then, let us consider the dominating operations which must be performed on the farm and deduce therefrom those distinctive requirements which must become a definite part of

2 Preparation of the seed bed, involving fertilizing, plowing, disking, harrowing, leveling, and packing

3 Planting of the seed, involving seeding, drilling, and planting

4 Cultivating the crops and destroying weeds

5 Gathering of the crops by such means as mowing, raking, loading, harvesting, and digging

6 Processing of these crops—baling, threshing, ensiling.

For these main operations power and transport equipment must first be provided. As the above operations changed from simple to more complex, the past 20 to 30 years have seen the power

source pass from man, ox, and horse, through a brief period and limited application of steam, to the internal-combustion engine. Here and there today the entry of adaptable electric motive power is foreseen rather than observed.

Owing to its inherent and increasing flexibility and adaptability, the internal-combustion motor has proved itself most popular. It also gives us control with the minimum of man power and the maximum of available power per unit of weight without necessary use of much auxiliary equipment and supplies. These

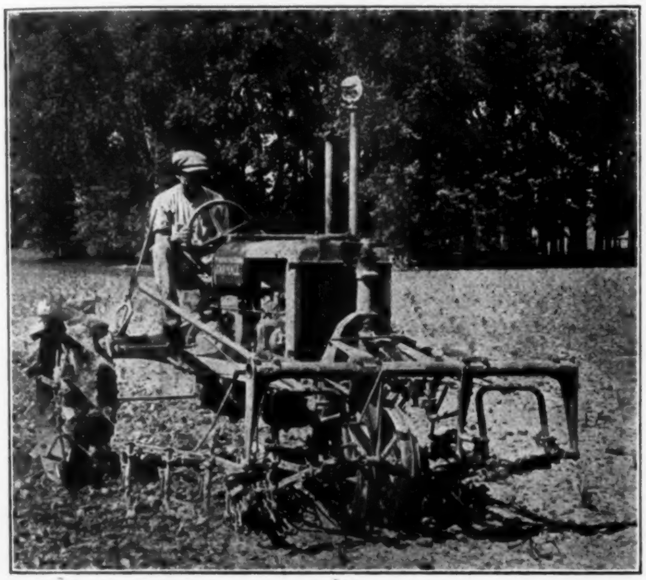

Fig. 4 The Tractor Has Motorized the Corn Crop
(Tractor power successfully dispatches this, the last but all important farm operation, long a stumbling block to horse elimination.)

Fig. 5 The All-Purpose Tractor
(After cutting and raking the hay, the all-purpose tractor also loads it. The following operation of baling or stacking is readily accomplished by tractor power from the belt.)

advantages have rapidly broadened its uses. Its popularity was helped markedly by the advances in automobile engineering, many features of which have fitted in nicely with tractor engineering; yet even in the engine details there have been definite divergences in design and many special features have been developed, owing to the special requirements and conditions which the tractor must meet. For example, the tractor's continuous sustained operation over irregular, rough, and dust-making surfaces has necessitated special attention to enclosure or other protection against dirt. This affects the point of intake of air to the carburetor as well as the straining from the air of dust by devices especially made for this purpose. Such provisions are now approaching their logical place as regular automobile equipment.

Other engine features which demand special attention are the custom of loading the tractor almost constantly at or near maximum, the slower operating speeds of from two to four miles an hour, the light weight of the entire tractor as compared with the power exerted, economy of fuel and lubricants on the road or in the field, and the successful operation with kerosene or gasoline as economy dictates.

Out of these and many other influencing conditions, after many

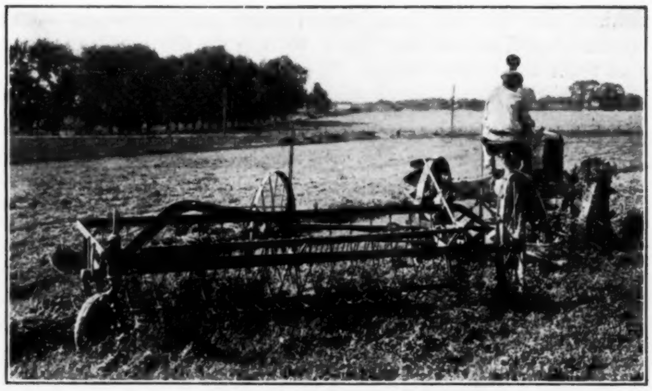

Fig. 6 Industrial Methods Successful on the Farm
(The cutting and raking of hay in one operation. One man with an all-purpose tractor is accomplishing the work formerly requiring six to eight horses and three to four men. The mower is driven from the tractor engine through the power take-off.)

Fig. 7 Mechanized Destruction of the Boll Weevil
(The great cotton crop of the South is being spared the ravages of this pest at the rate of 100 acres in a night.)

Fig. 8 Standard Plowing Unit
(Eighty years ago a man was doing well if he plowed an acre a day. A few years ago, before standardization on 2, 3, and 4 plow units, one outfit of three tractors pulling 55 bottom, plowed an acre in less than four minutes. This standard plowing unit enables one man to plow 12 acres in a 10-hour day, at an average power and labor cost of approximately $1.20 an acre.)

failures and many partial successes, there has been developed the cheap, light, convenient, reliable, and highly efficient farm tractor of today—a machine that appears to be as well standardized as the automobile in general design and capacity.

We are now witnessing a very definite enlargement of the tractor's scope from restricted use as a pulling machine to the ac-

tivities of planting and cultivating row crops. Quite recently we have seen its extension of useful power through the power take-off.

Due to this latter improvement we can now see important modifications in many farm machines as the wheels on drawn machines are relieved from their former function of furnishing a ground traction and the power to operate the machine comes direct from the tractor engine through the power take-off.

Between the farm tractor and the motor truck the large cost element of farm and road transportation is well cared for. The principal modification brought about has been the need for developing multiple equipment in the form of wagon and trailer trains. The tractor can thus utilize its drawbar capacity more economically, the design features needing special attention being the control of this train over a trackless path and making the train track. Overrun must also be cared for. There are many problems still to be solved in this respect for operation in hilly country. Low-down types of wagons for trailers might also be mentioned as developments toward economy of labor.

It may be desirable now to generalize for a moment on the dominating characteristics of mobile field machinery, since its design and operation must be coördinated with the motor units in speed, power, strength, and utilization in order to be effective. All such equipment must meet a wide variety of field conditions.

The area of mobile operation may be irregular in contour and the ground may be soft, hard, stony, sandy, or sticky. There are hillsides to deal with, flat lands, and valleys. This machinery is subject at all times to weather conditions, to heat, cold, moisture, and dryness. It is therefore obvious that the designer's viewpoint is distinctly different from that of one who meets indoor conditions where there are far less jolting and shock-producing operations and where expansion, contraction, and resistance to rust seldom appear as important factors.

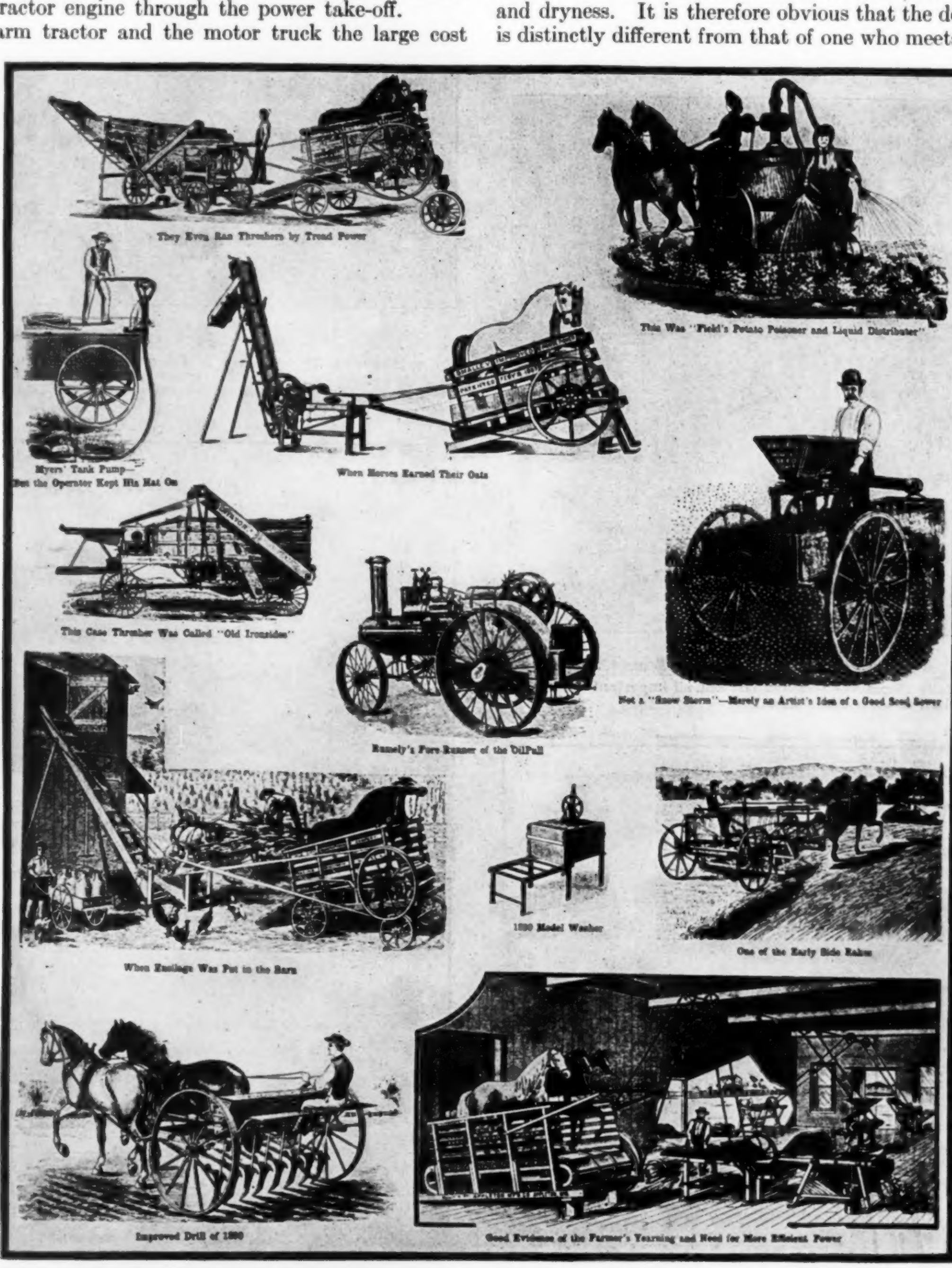

Fig. 9 A Vision of the Not too Recent Past; These Were Quite up-to-Date Tools a Generation Ago

From an operating standpoint the problem of maintenance is noticeably different from that of stationary machinery. Lubrication of different specifications for the widely separated bearings is necessary. Bearings must have a definite flow outward to avoid washing dirt or dust into them; the intended alignments of lightweight, flexible, yet strong parts must be reasonably maintained and still avoid weave or cramp that would interfere with satisfactory operation. Practically all repairs must be made in the field, away from shop facilities, hence speed is the essence of the repair. Accessibility and unit construction are both therefore

far more important than they are in other classes of machinery.

The controls must be convenient, certain, rangy, and responsive to the operator, who may be expert or without special skill. If the machine is to have a reasonable foreign market the design must meet an interesting variety of foreign requirements, characteristics, ideals, and traditions. Further, those of us in the farm-implement field who must consider foreign-trade requirements can say that there are French troubles, German troubles, Argentine troubles to meet; the Arab, the Turk, or the Russian each furnishes his special variants for the designer. Even a change in the color of the paint or the unnecessary enlargement of a part may be made in a perfected machine in order to give the foreign customer complete satisfaction.

In agricultural-machinery design the prominent fundamental operations must be met by a light, strong frame about which the designer builds combinations of operating units which shall function as intended and at the same time permit necessary simple modifications of attachments to be made to meet the needs of special crops or unusual conditions. The problem is therefore comparable with that of building a machine tool with its main governed operating parts provided with suitable jigs and fixtures to widen its usefulness and effectiveness. Reliability and simplicity must always be outstanding features of farm-machinery design.

A general glance over such machines as a mower, grain binder, side rake, grain drill, corn planter, or harvester-thresher cannot fail to impress the observer with its likeness of design to airplane construction, yet these agricultural machines are full of the most difficult problems for the designer. There are numerous wheels chains, cams, springs, trips, ratchets, irregular-shaped parts, braces, ties, intermittent-cycle operating parts which make mechanical drawings often as useful as a three-plane sketch of a brush heap. It is this feature which, for economy's sake, forces the processes of development into one of building around an idea until the machine can be reduced to record drawings. The system of using complicated samples rather than drawings as a guide in multiple manufacture also results in economy, speed, and simplicity in this kind of construction.

Another prominent feature of agricultural-machinery design is the necessity of meeting a wide range of adjustments of groups of parts one to another in order to deal with variations of soil or crop.

Take for example a 14-in. plow, set to cut 6 in. deep, and draw it at three miles per hour. In light, sandy soil the dynamometer might read as low as 150 lb., whereas in gumbo it might read 1800 lb. under hard conditions.

The mower might encounter thin, light grass, or heavy alfalfa. The binder may meet grain 12 in. high or 6 ft. The grain may be standing up straight or it may be lodged almost flat, so that the knife must barely skim the ground.

The wheat crop may be 3 bu. per acre or 40 bu., and special yields have run as high as 80 bu. per acre. The same machine must handle one extreme as well as it does the other.

The grain drill may be required to deposit evenly anywhere from $^1/_2$ bu. to 5 bu. of seed per acre; seed of oats might mean the planting of 15 lb. per acre minimum and of barley as much as 340 lb. per acre.

What would be the effect on a farmer if his grain binder missed tying a few bundles per hour? The binder must tie with a permissible miss of only a fraction of one per cent, in spite of the difficult physical variations. When the knotter is in good order, when no fault can be found with the twine as to size or strength, one can count on not over one miss to 1000 bundles. Whole days of operation are recorded without a miss.

In addition to these variable field conditions it should be remembered that we are in most cases dealing with a peculiarly light-weight product which is delicate to a considerable degree. The ripe grain in the field must not be too roughly handled, or shattering results with accompanying wastage. Such crops as peas or beans are particularly susceptible to injury in harvesting. If grain is handled by the thresher cylinder at too high a speed, cracking results, with loss in grading. If threshed too slowly, grain will not be removed and will be blown into the stack with noticeable loss. Similar delicacies must be considered when applying machinery to handling corn, beets, potatoes. Undesirable brushing, skinning, or other injury affects the keeping value as well as the salability.

If the entire range of machinery as applied to agriculture be reviewed, one cannot fail to see the extremes in fine and coarse construction which must be met. The delicate, high-speed cream separator, which must not miss even a small fraction of one per cent of the cream present in the milk, is one type. The separator when brought up to speed of 7000 r.p.m. and allowed to die under its inertia, will run for 22 minutes.

The simple, rugged plow is quite another. In operation the plow is a rigid unit. It must enter the ground to a predetermined depth, cut, raise, turn, reverse, and place a strip of soil, while at the same time it must cleanly and accurately cover trash, fertilizer, weeds, or other litter. In its highest form the plow today is but a play tool for the farmer, who, seated comfortably on the tractor, simply jerks a string to set his plows in the ground automatically, or likewise lift them.

The automatic power lift or trip is now applied to numerous farm tools, thus reducing the back-breaking heavy lifts formerly required of the operator. Release hitches are being similarly improved.

Years ago a man had difficulty in performing all needed operations on a farm of 20 acres. Today, with modern equipment, he can alone operate 160 to 320 acres, according to his crop. With five men and five 15/30 tractors, with three 14-in. bottoms, traveling three miles per hour, a farm of 640 acres can be plowed in 12 days, where formerly five men and ten horses took 64 days to cover the square mile.

Grain can be planted, cultivated, or harvested in a similar manner regularly and easily at the rate of 25 acres a day per man: 50 acres per day can be covered under pressure. One man with three boys handles nearly 2000 acres of Kansas land, year in and year out. These examples definitely indicate the progress which has been made in mechanizing applied to agriculture.

It has also been proved that yields per acre are increased as the result of using modern equipment. This is perhaps attributable largely to the timeliness of action with high-capacity machines requiring little or no hired labor. Night-and-day operation is also made possible by the interesting tractor.

These higher speeds reflected in the design of modern tools, their greater capacity, and earning power, have warranted the adoption by the farm-implement industry of every kind of high-grade material or device utilized in other lines. Material treatments are up to date and no apologies need be forthcoming on any score related to materials and their treatment.

Electrical applications will extend—to what extent time alone can tell—and already some startling indications are recorded, but it must be as apparent to the student who views our industry from the outside as it is to us on the inside that only a beginning has been made. This field is wide, and it is full of invitation and of challenge.

Lately we have seen the beginnings of some significant collective efforts in our field. One such effort is that of the National Committee on the Relation of Electricity to Agriculture which is actively and coöperatively analyzing the possibilities in that field through a series of well-considered research projects. Another effort along somewhat similar coöperative lines is that of the Committee on Farm Machinery Research which has undertaken a survey of numerous agricultural-engineering problems in all their phases. The Committee is organizing the work, reducing duplication, and assigning well-defined problems. Here we see the U. S. Department of Agriculture, the American Society of Agricultural Engineers, the agricultural colleges, the National Association of Farm-Equipment Manufacturers, and others coöperating to determine basic facts with a view to outlining efforts toward greater economic success.

Further, there is now before us another coöperative movement, that of the National Committee on European Corn Borer Control. This committee is working to meet the emergency created by an insect pest.

These examples of intensive coöperative study and action, though still young, have already indicated from numerous angles, possibilities of improved machinery, improved farm methods, of better products and better production per acre and per man.

Management of Industrial Power—The Executive's Viewpoint

By WALTER N. POLAKOV,[1] NEW YORK, N. Y.

0.10 The aim of this paper is to present a logical outline for an executive inquiry into an industrial power problem.

0.11 To get an adequate answer, one must be able to formulate a sensible question.

0.12 To become properly informed, one must secure necessary and sufficient answers.

0.20 It is easier to answer than to ask; the task of an executive is therefore not an easy one.

0.21 Soundness (therefore success) of executive direction depends upon the information the executive gets.

0.22 An executive need not be a power engineer if he can secure expert advice, but he must translate into action the knowledge of the best practice.

* * * *

1.00 It is essential that an executive, controlling industrial power, be at all times reliably informed as to:

I—What his plant can do
II—What his plant does
III—If it does not do it, why?

1.10 The questions, therefore, to which an executive must have reliable answers are:

Group A—Plant

1.11 Is the capacity of his plant greater than, equal to, or less than the requirements?

1.12 If capacity is greater than requirements, what shall he do with the excess capacity?
- a Scrap?
- b Secure outside load?
- c Carry on profit and loss account?

1.13 If capacity equals requirements, how shall he provide for:
- a Breakdowns and maintenance?
- b Peaks and unusual loads?
- c Future growth?

1.14 If capacity is less than requirements, how shall he secure additional power:
- a Eliminate waste or stagger peaks of consumption?
- b Purchase power?
- c Enlarge installation?

Group B—Operation

1.21 Is the realizable efficiency of his plant greater than or equal to the performance efficiency?

1.22 If performance efficiency is equal to set task or realizable efficiency, what are the conditions:
- a Of operating practice?
- b Of maintenance?
- c Of labor?
- d Of load?

1.23 If performance efficiency is less than the task or realizable efficiency, what are the causes:
- a Poor operation?
- b Neglected maintenance?
- c Fatigued, unskilled, or disgruntled men?
- d Unusual load?

Group C—Costs

1.30 Is the performance cost greater than, equal to, or less than the predetermined standard cost, based on task efficiency and standard prices for fuel, labor, and supplies (fixed charges are treated separately)?

1.31 If the performance cost is greater than standard (realizable) cost is it due to
- a Efficiency below the task (see Par. 1.23)?
- b Increase of market prices over standard?

1.32 If the performance cost is equal to standard cost, was it not due to simultaneous
- a Efficiency below the task?
- b Drop of market prices?
- c Proper performance fulfilled

1.33 If the performance cost is less than the standard cost is it due to
- a Task being set too low and exceeded, or
- b Price reduction on fuel or labor or supplies, or both?

Group D—Outside Power

1.40 The performance cost of generated power may be greater than, equal to, or less than the price of purchased power.

1.41 If the performance cost is smaller or equal in price to purchased power, then:
- a Is the plant so old and unsafe that it should be abandoned?
- b If so, is it possible to replace it wholly or in part to compete with outside power?
- c Is the plant so unreliable as to interruptions that outside power may be more dependable?

1.42 If the performance cost is greater than the cost of purchased power:
- a May the plant be totally discarded?
- b Shall steam for heating and processes be generated, and if so, at what cost?
- c Is the outside supply of power free from interruptions?
- d What do production losses amount to due to failure of power (overhead, ownership expense, spoilage due to interrupted process, lost wages, added hazard, etc.)?

Group E—Distribution

1.50 Is the cost of power correctly allocated to:
- a Forms of power used?
  1. High-pressure steam
  2. Low-pressure steam
  3. Exhaust steam
  4. Steam power (shaft drive)
  5. Pneumatic power
  6. Hydraulic power
  7. Refrigeration
  8. Transportation
  9. Electric power
  10. Electric light, etc., etc.
- b Application of power? distributed
  1. By departments
  2. By grades of product
  3. By kinds of product.

* * * *

2.00 The above state of affairs can be described; not named.

2.10 From descriptions of conditions and methods under which the desirable results may be expected,

Standard Practice Instructions
and
Standard Operating Costs

can and must be worked out.

2.11 This work can be done for an executive by a competent power engineer, provided that he is not interested even subconsciously in:
- a Setting tasks too low to protect operating force from criticism
- b Representing standard cost too low, attempting to assure employment
- c Setting task too high to boost the design and construction of equipment
- d Representing standard cost too high, favoring purchase from outside.

2.12 Competency of a task setter in an industrial power plant must also cover the adjoining fields of:
- a Technology of processes requiring power, heat, etc.
- b Economics and factory accounting
- c Psychology and the role of the "human element" in industrial problems.

* * * *

3.00 An executive must be informed
1. continuously
2. adequately, and
3. reliably

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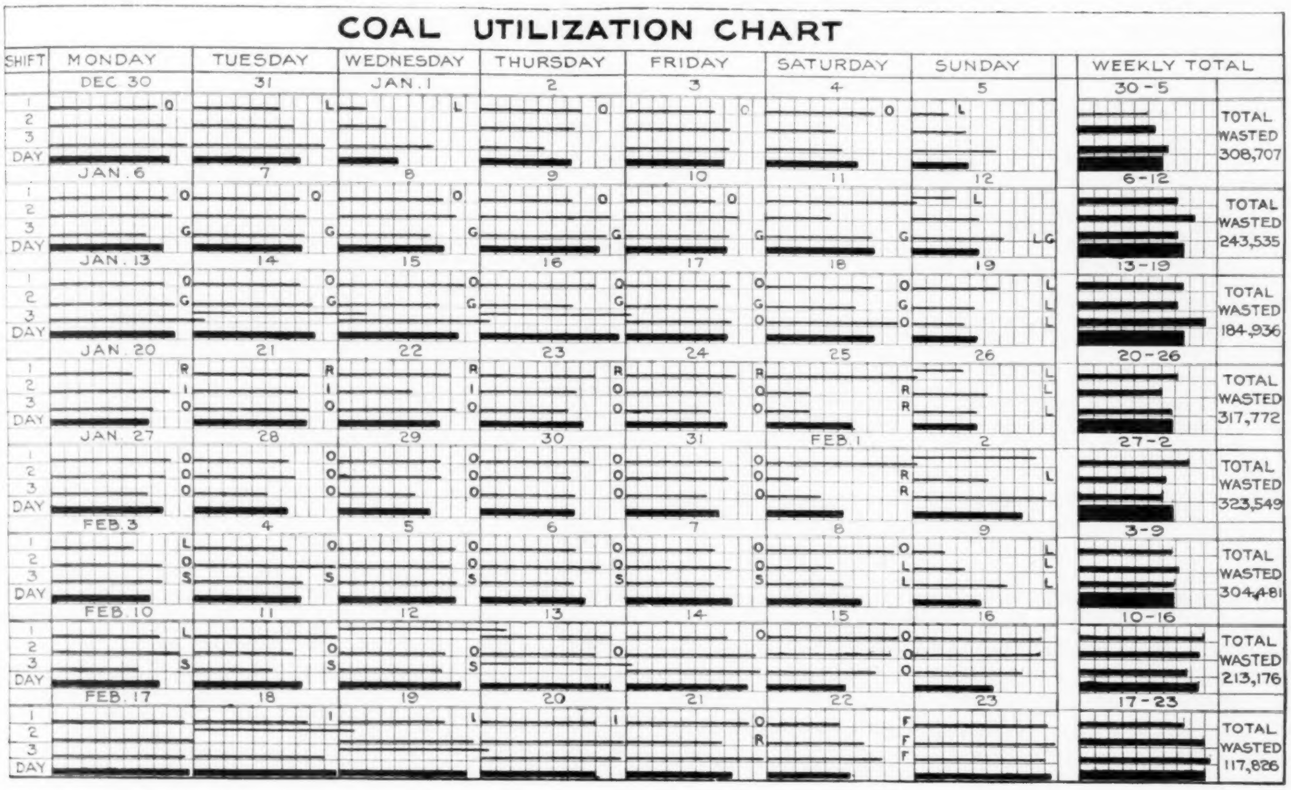
[1] President, W. N. Polakov & Co., Inc., Mem. A.S.M.E.

Contributed by the Power Division and presented at the Spring Meeting, White Sulphur Springs, W. Va., May 23 to 26, 1927, of The American Society of Mechanical Engineers.



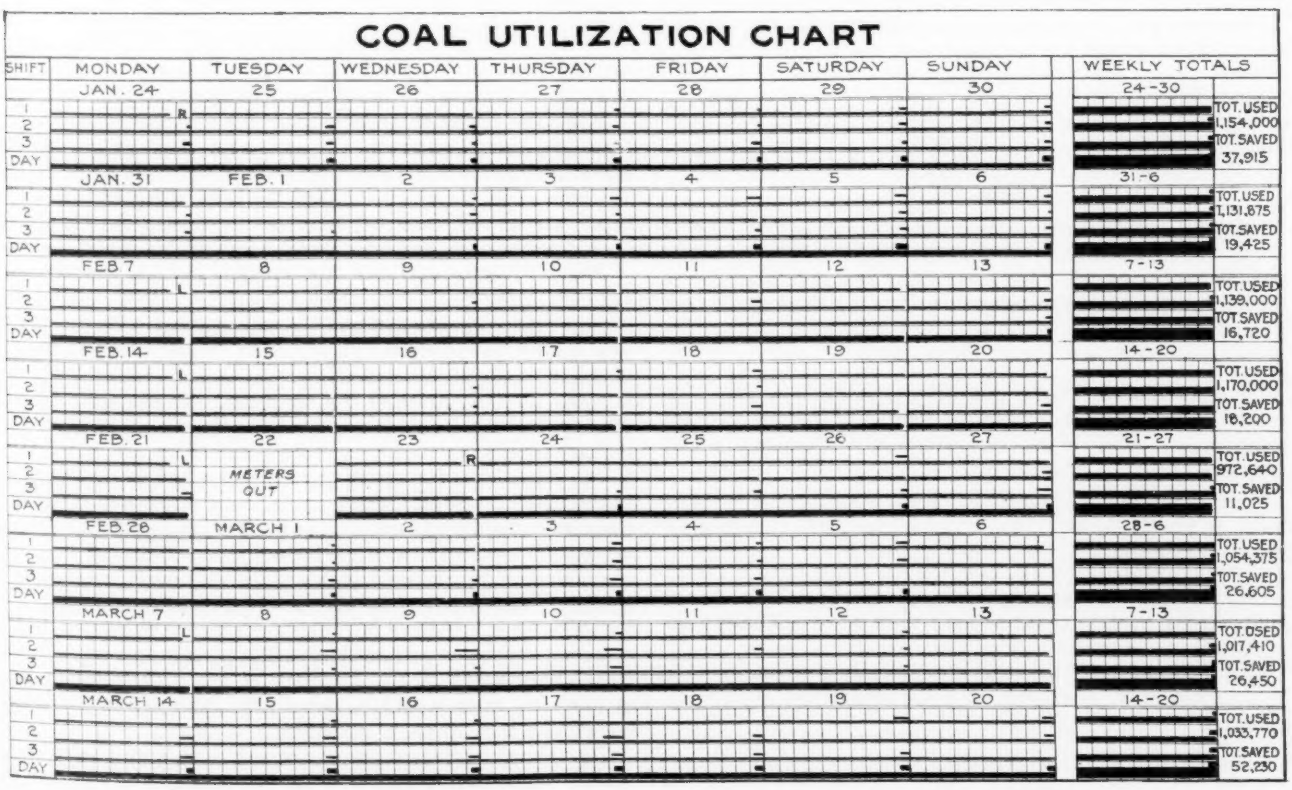


Fig. 1

G—Green operator
O—Operation poor
R—Repairs needed
S—Substitute fireman working
F—Fuel causes trouble
L—Load unfavorable
I—Instruments inaccurate

as to comparison of *what was done* with *what should have been done.*

3.10 This information must be presented to an executive in a form ready *to indicate action.*

3.11 Analysis of a mass of details consumes time and distracts attention. Therefore information given to the executive must clearly state whether the task was done, and if not, *why not.*

* * * *

4.00 To meet this requirement of comparing actual facts with desired, we make pictures of facts.

4.10 The chart pictures the fact in logical space. It is a model of reality.

4.11 The extent of the space for the period recorded is the extent of the desired fulfilment.

4.12 The extent of a bar on the chart is the extent of the accomplishment.

4.13 Thus the performance chart is linked with reality. The extent of accomplishment on the scale of predetermined task is a logical picture of performance.

* * * *

5.00 Fig. 1 shows a form that serves the purpose effectively. The length of each daily space represents on the chart the task set for any operation. It might be in terms of required pounds of steam evaporated per pound of fuel used, or per cent of boiler-plant efficiency, or pounds of fuel per kilowatt-hour generated, or pounds of steam used by turbine plant per kilowatt-hour, or ratio of fuel used to product processed, or number of boiler tubes turbined or condenser tubes ferruled, etc., or in any other suitable unit. The straight bars drawn for each shift of a day are shorter if performance falls short of the requirement, or equal to or extending beyond the daily spaces if the task set was met or exceeded.

5.10 From such a chart the executive sees whether the plant is doing as well as it can or not. If not, his question is, Why not?

5.11 At the end of each short bar he sees a symbol—a letter by which the operating engineer denotes the cause of the failure to live up to the task, as, for instance:

G means "green operator"
R means "repair needed"
F means "fuel causes trouble"
L means "load unfavorable"
M means "man inattentive" etc.

5.12 Being informed what the plant does as compared with what it can do; an executive may call the chief engineer into conference to discuss what measures must be taken in order to prevent in the future the recurrence of falling short of the task performance.

* * * *

6.00 The next thing is for the executive to know how much his power costs. Mere accountant's figures of power cost are meaningless, since under various conditions expense would vary irrespective of operating efficiency.

6.10 When dollar and cents' cost per unit rises it does not necessarily mean worse operation, as this may be due to conditions beyond operating control. (See Par. 1.31 ff.)

6.11 It is advisable, therefore, that the executive have a report prepared for him in a graphic form. A chart is easily prepared picturing the relation of the actual cost of power (or each form of power) to the predetermined standard cost of power.

6.12 That the elements of the chart are combined with one another in a certain way, represents that the things actually are so combined with one another.

* * * *

7.00 To translate the knowledge of failure into an act of improvement is a job of an executive.

7.10 Assuming the knowledge of the best operating *method* and the *means* for doing a good job as given, the variable is the *will* to apply knowledge to means.

7.20 The job of an executive, therefore, is to stimulate the will to do better.

7.21 The first step in this direction is to establish a goal, the point to strive at, to set *the task.*

7.22 The second step is to make this striving for perfection *fascinating.*

7.23 The third step is to offer an additional reward to those who learn, i.e., offer to those who learn *a bonus.*

7.30 Avoiding failures is more important than correcting them; training is more important than discipline.

Discussion

J. M. SPITZGLASS[2] wrote that his attention was attracted by the novelty of the form in which the subject-matter of the paper was presented, i.e., the notation of the paragraphs in the decimal system. Only those who were accustomed to work from outlines (and all engineers should be) would appreciate the advantages offered by this system. The possibility of further expansion without confusing the sequence of the outline, and the segregation of the items created the proper decisions.

Mr. Spitzglass wondered how many people realized the truth of paragraph 0.20, that it was easier to answer than to ask questions, that was, if the question and the answers were to be of any value. Having an outline of this kind, with the subjects grouped in order, the questions and the corresponding answers would follow in natural order, and nothing essential would be omitted when the data were obtained. He believed Mr. Polakov had made a wonderful contribution to the profession by giving this systematic outline.

Wallace Clark[3] wrote that in the paper the author had presented to the managing executive a technic of control of industrial power, setting forth clearly what information was needed for effective control, how standards could be determined, and, finally, how actual performance could be compared with these standards in such a way as to induce executive action.

Such a method as this went a long way toward simplifying the power problem, which was usually a troublesome one for the executive who had not had a technical education in the generation of power. It told him whether or not he should be satisfied with the service and cost of this part of his plant, and, when conditions were not satisfactory, it guided him to the discovery of the obstacles preventing the attainment of his objective.

When the causes of inadequate service and unnecessary expenditures had been located and the action for their control indicated, it still remained for the executive to take that action and he would welcome a technic which simplied the facts in regard to conditions in his power plant and left him free to concentrate his attention on the solution of problems which required his expert judgment.

Henry F. Scott[4] said that Mr. Polakov had brought out clearly the convincing manner in which the problems under consideration could be placed in the hands of the management. He thought that was a good procedure for all engineers to follow where the plant engineer might be concerned with the minor problems which did not call for the advice of the specialist. At the same time Mr. Polakov had illustrated how convincing they could be made to the management.

The stimulation for better performance which he had mentioned in the power house had begun in the use of steam and power in the manufacturing departments. The illustration made by Mr. Scott in his paper[5] showing the attitude taken by an accounting department of a manufacturing plant was one which he thought was more or less common to most industrial plants. It showed the difficulty which the engineer would have in providing a means to measure the use of steam and power, and until he could provide some measure which would be brought to the attention of the department managers in industry, there would be some little difficulty in getting that incentive across to those managers.

The discussion that followed seemed to indicate, only in more detail, some of the problems of the power plant.

[2] Vice-President, Republic Flow Meters Co., Chicago, Ill. Mem. A.S.M.E.

[3] Consulting Management Engineer, New York City.

[4] Plant Engineer, Dennison Mfg. Co., Framingham, Mass. Mem. A.S.M.E.

[5] Management of Industrial Power—The Engineer's Viewpoint, pps. 853–856 of this issue.

Management of Industrial Power—The Engineer's Viewpoint

Contacts Which the Management Should Have with the Power-Plant Problem—The Responsibility That the Management Should Delegate to the Engineers Who Supervise the Work

By HENRY F. SCOTT,[1] FRAMINGHAM, MASSACHUSETTS

THE diversified requirements of industrial power make it extremely difficult to outline and compare engineering work as it relates to industry.

The generation and distribution of power, light, and heat are, however, problems which are common to most industries, and their importance in the field of mechanical engineering depends considerably on the size and character of the industrial plant.

It is the purpose of this paper to discuss contacts which the management should have with the power-plant problem, and to outline the responsibility that the management should delegate to the engineers who supervise this work.

This paper may not bring to light new or undeveloped processes or performances, but it may help to define the field of engineering as applied to industrial power and to bring about a common understanding of this subject by the management.

There is every reason to consider the power plant as a separate concern, or a subsidiary company within the plant, responsible for supplying (generated or purchased) power, light, and heat and possibly other services, together with the transmission and application of this service.

The management should demand the same executive ability from the head of this department as from the head of any manufacturing department, and his standing and relation to the management should correspond to that of other department heads of equal responsibility. The power house should be operated with at least the same degree of safety and cleanliness, and should maintain the same standards of performance that exist in the manufacturing departments.

Need of Complete Accounting System for Power Plant

Often the returns on investment in manufacturing departments are greater than those made in the power house. Consequently, though certain power-house investments could be made from which returns would be sufficient to warrant making improvements (if considered independently, weighing savings against reasonable interest and depreciation on investment), frequently they are not made. The need of them can always be determined by comparing the power plant cost of operation with past performance, with the estimated cost of purchased power and heating plant, with a more modern plant, and with outside plants. On this account a complete accounting system should be set up, showing the quantities and costs of raw materials used, and the cost of manufacturing and distributing the product.

The value of a clear understanding of this subject on the part of the management is, perhaps, more essential in the smaller plants, where the operation of the power plant does not come under the supervision of an engineering department. In the large industrial plant all of the engineering work may be in the hands of qualified engineers, and their supervision of the work connected with the power plant may relieve the management of much of the responsibility of the development, generation, and application of power.

In any case, the responsibility for this work should be delegated to an engineer of sufficient ability and experience to be able to supervise it properly; one who is competent to advise the management concerning its development, and who is capable of deciding when to call upon the experience of specialists and other engineers.

On account of the refinements which are taking place in manufacturing methods and the extent to which scientific use of power and heat is applied to process, it is often necessary to depend upon the service of engineers with a high degree of mechanical training. Many managers will depend upon hiring from outside the plant such service as they require—an arrangement which may be very satisfactory in connection with the major problems, but not so satisfactory with the problems which occur from day to day. These must be given equally careful attention continually, if reasonable economy is to be obtained during the life of the equipment.

In states where laws relative to the operation of power equipment have been passed, the operating engineer has become more of a specialist. The old type of operating engineer who worked by "rule of thumb" method, and who had little knowledge of the complex nature of the equipment for which he was responsible, is gradually disappearing as he can compete no longer when the cost of operation is analyzed and where purchased power may be available.

In most industrial plants engineering work is an important factor, but the responsibility and results are difficult to measure. In the power plant, however, there is every opportunity for the measure of responsibility and performance, and the management has every reason to expect continuity of service, and economy in the production of power, light, and heat.

Extent of Responsibility of Power-Plant Engineer

The responsibility of the power-plant engineer extends not only to the operation of the plant in accordance with state laws or regulations, but also in accordance with standards of safe practice in respect to both employees and equipment. The standards of safe practice found in the boiler codes prepared by The American Society of Mechanical Engineers, or others drawn up along similar lines, have been adopted by most states.

One important consideration in connection with safe operation is the inspection by state departments or by insurance companies. However, similar inspections, made by the person who is responsible for the power plant as a whole, should supplement the official inspection as constant supervision is necessary.

Where, within an industrial plant, is there such expensive equipment under the supervision of a few men as in the power house, and where else in the average industrial plant can a few moments of inattention or carelessness on the part of an operator cause the plant to close down for weeks or perhaps months? These facts point to the necessity of selecting competent men for this work. But it must not be forgotten that the engineer cannot perform his work successfully unless he has the confidence and support of the management.

For the most part the engineer in the smaller plants has received his training through experience. With improved apparatus and with the more general use of electrical distribution of power, he has had to gain sufficient knowledge to operate such equipment safely under normal conditions. When unusual situations occur, the management may have to depend upon outside resources to give him assistance, but those responsible must be sufficiently familiar with the plant as a whole, so that they can act quickly in case of emergency.

As the operation of the power plant is not limited to the production period of eight or ten hours per day, the responsibility for having steam available outside of working hours for fire pumps, heat for buildings, and power for light and equipment must not be overlooked.

This all leads to continuity of service, which is of prime importance, whether the power is generated in an isolated plant, or whether purchased power is used. Many isolated plants have operated for years without a shutdown, a record which is comparable with that of most central stations, and surpasses that of many plants

[1] Plant Engineer, Dennison Mfg. Co. Mem. A.S.M.E.

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which are dependent upon transmission lines to carry power a few miles from those same central stations.

Another phase of continuous operation which should be of interest to the management is the question of insurance, either in the way of daily indemnity in case of a shutdown, or, what may be more important, reserve equipment or "stand-by" service which frequently can be obtained for a lesser amount of money than the cost of use and occupancy insurance.

Important Consideration in Development of Power in Service to Manufacturing Departments

In most industries the important consideration in the development of power is service to the manufacturing departments. The most frequent misunderstandings occur in the regulation of such service. Meters and recording instruments help to prevent misunderstandings, especially outside of regular working hours when there are some special conditions concerning processes which extend over that period. A call for extra power on holidays or at night may interfere with important changes or repairs which can be made only at that time, or it may lead to an unwarranted expense. Such questions should be decided by the management and, except in extreme cases, a sufficient warning should be given to allow the proper arrangements to be made.

Maintenance of equipment, especially in the anticipation of repair work, is greatly influenced by the care with which inspections are made. In industrial plants where the engineering work, as a whole, is conducted as a separate function, the power-plant engineer may be relieved of a considerable effort in this direction, but not to such a degree that he can avoid the responsibility or supervision of equipment under his control. In some states the power-plant engineer is personally responsible for the condition of steam lines extending into the plant, but even where such supervision might not be required or be essential, his responsibility should be recognized by the management.

Economic operation of the power plant is the conversion into steam of the energy contained in fuel for heating or for the generation of power, with the minimum loss of heat units. If the use of heat did not extend beyond the power house the measure of economy would be comparatively simple, but in the industrial plant it is complicated by the use that is made of the steam at high or low pressures and by the wastes that occur, either from necessity or by improper control, or improper methods of distribution and application.

The knowledge of the power-plant engineer should be sufficient to control properly the combustion of fuel and maintain proper conditions in regard to draft, temperature, and quality of flue gases. In this connection suitable instruments for determining these conditions are essential.

The management should realize the necessity for expert advice upon feedwater treatment, as this proposition involves chemical research work beyond the scope of the facilities and personnel in the average industrial plant. Improper treatment of feedwater creates conditions within the boiler which decrease the efficiency through losses occurring in the heating surfaces. Many mechanical failures in the boiler can be traced directly to improper feedwater treatment. Certain boiler compounds that are sold for this purpose are actually injurious to the boiler, and the life of the equipment may be materially reduced. In any case, it is necessary for the power-plant engineer to have a sufficient knowledge of this subject to adapt his practice to the standards derived by the chemical engineer.

In the existing plant the engineer may work with some disadvantage on account of the fact that the units are not suitable for the conditions of load, and that he may not be able to obtain reasonable economy over short intervals. Nevertheless he must distribute the load to the equipment in the best manner possible, and allow his knowledge of sudden demands to influence his judgment. Auxiliary equipment, service equipment, and certain manufacturing processes, and purchased power frequently offer a means of balancing the load to obtain more efficient operation of the plant as a whole.

Sources of Loss and Their Prevention

Where steam is used for process and heating, serious losses may occur in the plant on account of the wasting of hot water. The prevention of such losses may be brought about by more careful control in the manufacturing departments and by improvements which may be made in their equipment, but the engineer must look to the management for assistance in getting the power coöperation from the manufacturing departments.

Another source of loss is in connection with trapped high-pressure lines, and a visible means of indicating this waste gives the power-plant engineer an opportunity to have it corrected.

It is the responsibility of the power-plant engineer to watch the changing conditions as the capacity of the plant is approached, and the management should be given sufficient warning in order to be prepared to consider additional equipment when necessary.

Tests made when equipment is installed show what it is capable of doing and assures the management that the guarantee of the manufacturer is fulfilled. Similar tests subsequently made will show the condition of equipment, but continuous tests showing what the plant actually does over a period of time and under the usual working conditions is very desirable for the management's use.

Suitable means of weighing or measuring the fuel, and a means of measuring the water evaporated or steam produced almost always can be procured when the management is informed of the possible savings that can be made through having instruments for these purposes. All modern plants are equipped with not only such facilities, but also with many other types of indicating and recording apparatus.

Information Made Available by Recording-Instrument Charts

Frequently the management does not realize the information that can be found in the charts from recording instruments in the power house. Losses in production at starting and stopping time show very plainly on the load charts. Improper temperature control in buildings, and delays in starting processes where steam is used, can often be analyzed from the chart of a steam-flow meter. The use of instruments for measuring output is absolutely necessary if bonus systems are to be applied or any form of wage payment adopted on measured production basis.

With graphic records and accumulated data it is possible, when planning a new installation or increasing equipment, to reconstruct the conditions which existed at any period during the life of the plant. This information often is necessary to supplement calculations which may be made, especially when such calculations cover only a short period of operation.

Power-plant costs can be very convincing if the accounts are so distributed in the manufacturing plant that the power house appears as an independent unit. The charges for fuel, payroll, supplies, maintenance, fixed charges, and administration can easily be distributed to the power plant and become the basis of the cost for power, light, and heat delivered.

Where only one product is manufactured the cost of operation of the power plant is frequently figured against the units of output, but this does not eliminate the necessity of arriving at a true cost of steam and power. The management should be supplied with concise figures concerning units with which they are familiar such as cost per thousand pounds of steam and the cost per kilowatt-hour, together with the reasons for any discrepancy between these costs and the cost which might be obtained under ideal conditions.

Lowest costs would be obtained ordinarily when the plant is designed to operate the equipment at full capacity, and when manufacturing departments are running at 100 per cent production. With a growing plant, however, this condition does not usually exist, except for short periods. Unless the units have been selected with a view to operating efficiently over a wide range, the cost of power may be excessive when the output of the plant decreases to any great extent.

A comparison of power-plant costs in industrial plants is of value only when sufficient details are known in order that proper consideration may be given to points of similarity. Figures for comparison should be simple and should cover items which are common to the greatest number of plants.

Attempts have been made to develop codes for continuous per-

formance of boiler plants. Those who have studied these developments have found that it is common practice in boiler plants to divide the operating charges into fuel, labor, supplies, and maintenance. These figures can be used for comparative purposes.

In the individual plant the expense for fixed charges and administration can be added to the operating charges to determine the total cost of a thousand pounds of steam.

Purchased Power

Purchased power is frequently a factor in the development of a power plant, being more or less in proportion to its proximity to central-station service. This practice is developing rapidly, and statistics show that there is a falling off in the number of small power units which are being operated in isolated plants.

The possibility of purchased power may be present when a power plant is designed, or it may become a factor at some time during the life of the equipment. It is frequently useful during periods when, on account of the design of the plant or on account of irregular demands, the isolated plant cannot produce a portion of power as cheaply as it can purchase it.

Contact between the power engineer and the purchasing department has much to do with the successful operation of the plant. When lubricating oil and fuel are purchased by the purchasing department, the basis of the selection should depend greatly upon the results obtained in use. Today many of the large oil companies, after making a study of a plant's equipment, will make recommendations as to the proper kind of oil to use for different kinds of lubrications. Usually such advice has been found to be reliable.

The purchasing department must depend upon the power-plant engineer and the testing laboratory for information about the economy that can be obtained from any kind of fuel. Any one responsible for the purchase of coal, although he may not have had the training of an engineer, soon learns that the coal with the most heat units may not be the most economical fuel to burn. Depending upon the type of furnace, with other things being equal, the selection of coal may be dependent upon the percentage of ash, the fusing point of the ash, and other properties which are of importance.

Plants which handle comparatively large amounts of fuel must provide for sufficient storage so that the purchasing department may buy at attractive prices, or in anticipation of a shortage, but the responsibility for decision upon this policy usually does not rest entirely on the power-plant engineer. Storage of coal often becomes a difficult problem as spontaneous combustion may occur, and as considerable of the heat value may be lost if proper care is not used in storage. Transportation of fuel to the power plant and within the power plant is also a source of expense, and there should be a common understanding between the power-plant engineer, the purchasing department, and the management as to the most economical and dependable method of transportation.

Plant Design and Relocation

When a plant is being built or moved to a new location, the natural advantages of the location in regard to the soil, water supply, drainage, and storage of fuel should be given early consideration. A plant engineer who is constantly in touch with the manufacturing problems may be of great assistance to the management and the consulting engineer who may be employed, in deciding what type of equipment should be provided. His knowledge of varying demands for both steam and power may be a deciding factor in determining the kinds of units to install and the method of distribution.

The plant engineer cannot hope to compete with the specialists who are engaged in designing power plants for the most economic production of power, the conservation of resources, and distribution of power. The specialists, on the other hand, can take the opportunity of coöperating with the engineering department or the power-plant engineer in the development of any power problem.

If the plant engineer has the support and the confidence of the management, many of the faults can be avoided which might come to light after the plant is in operation.

At the time the plant is being constructed it is comparatively easy to obtain necessary approval from the management to cover the installation of equipment which will lead to economy. From an engineering point of view this condition should exist during the life of the plant, and the management should coöperate with the engineer in any effort to purchase such equipment as is necessary to conserve fuel and labor.

In an existing plant, conducted in a manner such as we have described, a great mass of detail will be accumulated which will be of vital importance when a new plant is being designed. With such information and knowledge as the power-plant engineer may have acquired, a forecast for future requirements can be made. Furthermore, the management will be provided with much of the information which is necessary to make a logical decision regarding the proposed equipment. Such a decision will be influenced by the consideration of growth and by surplus equipment which might be considered necessary as a matter of insurance.

At this stage of the problem the determination of the amount of power to provide for should be influenced more by the management than by any outside authority. Special requirements which may be necessary on account of the demands of the production departments should be studied carefully. Once again, the plant which has an organized engineering department has the advantage over the small plant where the operating engineer may not be familiar with the manufacturing processes.

Selection of Equipment

The selection of equipment should, as far as possible, be made with the approval of the power-plant engineer, regardless of the fact that it may finally be left to the judgment of the engineering department or to consulting engineers. Where the power-plant engineer's knowledge of equipment is limited, sufficient time should be allowed for him to see the equipment in use and to familiarize himself with its problems.

The actual construction of the power house involves many branches of engineering, some of which may be beyond the capacity of the power-plant engineer. The management is usually dependent upon outside engineers to supervise this work, as there are comparatively few plants that have an organized engineering staff sufficiently flexible to take over large problems of this nature.

The engineering problem in industry will be ever changing, and the use of steam for heating buildings, and for process work in manufacturing must eventually go through the same analysis that the use of steam is now going through in the development of power.

The more progressive industries are paying considerable attention to this subject today, but there is still a great amount of waste in the present methods. The waste of steam in manufacturing processes and the resulting loss of fuel will be open to just as much criticism as the waste of steam which now occurs in the generation of power.

The realization on the part of the management that these engineering problems require considerable combined technical ability and experience should lead to the careful selection of plant engineers. With the constantly increasing responsibilities in plant engineering this work will take its proper standing in relation to other departments in industry, and the management will have a much larger field of engineers from which to make a selection.

While considerable standardization has taken place in power-house practice in industry, much of the future development will depend upon the resourcefulness of the engineers in charge of this work and the coöperation of the producing departments and the management.

Discussion

F. M. GIBSON[2] wrote that the type of engineer whose viewpoint was discussed was the engineer who considered that the industrial boiler and power houses constituted a complete manufacturing plant, producing a certain amount of product at a cost from raw material, that sufficient accounting of performance and cost should be maintained, and that any decisions regarding the management of the boiler and power houses should be determined by an intelligent study of the records. This engineer's disagreement with management might be said to vary directly with the extent to which his viewpoint was denied. Very rarely did one find any serious difference between the viewpoints of the engineer and the

[2] Plant Engr., Am. Sugar Ref. Co., Boston, Mass. Mem. A.S.M.E.

management in a plant where there were sufficient operating records.

There were various reasons why some managements did not maintain records. Until two or three years ago, one read very little of the many excellent industrial power plants that were being built. The central stations introduced most of the new equipment and methods and the technical press found greater news value in those stations. Most articles dealing with industrial power plants stressed the great waste of fuel caused by inefficiency and mismanagement. Salesmen of central-station power did not neglect the opportunity to take advantage of the situation to convince management that industrial plants were inefficient and very costly. To many managements, the power plant became a necessary evil, they did not understand its operations and failed to give it the same consideration that was given to other departments. The continual drive to improve economies, the exacting rules for cleanliness and accommodations that were practiced in other departments, were not practiced in the power plant.

Some managements were swayed by prejudices. They would hear of some management that had invested in new equipment upon the advice of engineers and had not experienced a reduction in power costs: therefore no dependence was to be placed upon the engineers. Many consulting engineers had jeopardized their reputations by being compelled to predict efficiencies and costs of a new plant upon estimates of the power and heating load. Some managements had a prejudice against public-utility corporations and would not consider purchased power. Their prejudice would be dispelled in many cases if they had records to show the actual cost of generating their own power.

Managements sometimes failed to keep proper records because the situation had not been properly placed before them by the engineers. Some managements believed that the two items, namely, pounds of fuel and cost of fuel per unit of product, were sufficient. In such cases, when an increase in these unit figures occurred, it was impossible to tell whether the inefficiency had taken place in the power plant or in the production department.

The failure to install an adequate system of records of performance and cost was not confined to smaller plants but existed in many large plants. Less than a year ago an industrial plant consuming up to 700 tons of coal a day had installed for the first time a system to determine the efficiency of operation and the cost of power. Another plant, consuming approximately 100,000 tons of coal a year had finally been convinced that pounds and cost of fuel per unit of product were not sufficient information and had installed an adequate system of records resulting in a saving of 30 per cent of fuel per 1000 lb. of steam, and later a reduction of 20 per cent in the use of steam in process per unit of product had been effected. In another large plant the cost of fuel represented 60 per cent of the total cost of manufacture. A highly developed system of accounting provided for a scrutiny of all details of the other 40 per cent of the cost of production, but there was no detailed accounting system to indicate the waste in consuming the 60 per cent of the portion total cost. In comparison with some of the large plants mentioned, attention was called to the case of a small plant reported in a recent number of an engineering magazine. This plant was reported as operating with an overall boiler plant efficiency of 80 per cent for a period of one year. Considerable credit must be given to the management of many small plants who had intelligently studied their problem and installed a system of records commensurate with the amount of expenditure involved in the operation of their power plant.

Donald Ross-Ross[3] wrote that there was one feature which should be brought out at this time; namely, the necessity of proper scheduling of power or steam where the plant was sufficiently large to warrant dispatchers; or a method of signaling between manufacturing departments and the power house where the size did not warrant the extra salaries of dispatchers. Such forms of coördination were instrumental in obtaining higher efficiencies and lower power costs, especially in plants of high-process steam or power-load fluctuations.

In the pulp and paper industry, scheduling of process steam could be made a fine art, where a steam accumulator was installed. The amount of steam delivered to the accumulator and the amount taken from it was measured. A continuous balance was kept and, knowing the likely demands of the mill as a whole, over short periods of time, it was a simple matter for the dispatchers to requisition on the boiler house so many thousand pounds of steam an hour over these periods. This meant that the boiler ratings might be kept constant over definite intervals of time and ample time allowed for a change to a different rating. The whole scheme tended to higher boiler-plant efficiencies.

Alex D. Bailey[4] said that industrial power was generally, or had been, a small item of industrial production cost and consequently had not been given the attention that is deserved. As industrial plants increased in size, however, the total cost of power increased somewhat in proportion, and the point had been reached where the amount of money involved justified the expert ability which some of these plants were getting.

From the management view, first of all, a good reliable engineer was necessary. If the management did not realize the importance of power and the necessity for sound professional advice, the solution of the problem was not even started.

Further, if a plant or an industry was in the condition where the power-production end of the business was sick, then a complete analysis was essential and absolutely necessary to find out the ailment and what could be done to remedy it.

Chapin Hoskins[5] said that one reason why there should be and was likely to be more interest on the part of management from now on, was that margins of profit were apparently getting narrower in industry.

If one plotted the curve of the result of a cost cut, as the profit margin narrowed he would find something very surprising. If he had a 50 per cent margin of profit and made a 10 per cent cut in the total manufacturing cost, he would get only about 10 per cent increase in profits; but in case there was only a 10 per cent margin of profit, and a 10 per cent cut was made in the cost, he would get a 90 per cent increase in the profit. Therefore, as the profit margins narrowed, a 1 per cent cut in cost was important where it was not of any particular interest to the manager a few years ago.

W. N. Polakov[6] said that the most important point brought out in the discussion from the executive point of view was the relative cost value of the power from the point of view of manufacture.

First of all he would emphasize the fact that a kilowatt-hour or a pound of steam cost so much per unit or so much per month or year and that was relatively unimportant. It was a great deal more important from the executive point of view that the process of production should go on without interruption or spoilage. Next of course was the statement that the margin between the selling price and the cost of production was getting narrower and narrower.

In the sugar industry the ratio of coal to pound of product was approximately 7 lb. coal to 1 lb. of sugar. In the textile industries it was anywhere from 2 to 5 lb. of coal per pound of cloth. In the rubber industry it took from 2 to 6 lb. per pound of rubber.

Coal costing $6 on the grate meant about one-third or one-quarter of a cent per pound of coal burned, which gave a very large competing margin for the executive to consider whether his particular product could compete with another product of another manufacturer, or whether he could cut down or give a discount or inducement to a middleman or wholesaler, etc., or in large quantities whether he was warranted in making a certain reduction in price. He had known cases where millions of yards of cloth had been contracted for to be finished and because of the size of the order a certain discount had been made and this discount had eaten up more than all the profit which would have been a clear loss, if at the same time the concern had not decided to spend about $10,000 on complete new equipment and save that marginal the eleventh hour after the order was signed.

So, it would be seen that an executive would demand very often from an engineer, operating or consulting, that he should be not only an engineer but somewhat of an accountant, somewhat of a merchandising man at the same time.

[3] Engineer, Howard Smith Paper Mills, Cornwall, Ont., Canada. Jun. A.S.M.E.

[4] Superintendent of Generating Stations, Commonwealth Edison Co., Chicago, Ill. Mem. A.S.M.E.

[5] With *Factory*, Chicago, Ill.

[6] President, W. N. Polakov & Co., Inc., New York. Mem. A.S.M.E.

Balancing Factors in the Use and Obligations Covering Ownership of Freight-Train Cars

By L. K. Sillcox,[1] Chicago, Ill.

In this paper the author discusses the development of railroad equipment to date and points out some of the principles to be observed if railroads would continue to expand and become more efficient transportation agents.

The functions of transportation are first defined, following which is a general discussion of the limitations of railroad capacity because of terminal facilities. Terminal expenses also are treated at some length. There is a discussion of the slow-freight problem and recommendations for speeding up traffic are made. The matter of attaining the greatest utilization of equipment and materials is emphasized and recommendations made. Under this part of the paper the latest methods of car and locomotive repair are mentioned and their effect on the movement of freight emphasized. A very important part of the paper deals with the depreciation and retirement factors. A discussion of the aspects of design shows the great opportunity of engineers to assist in the solution of the problem of transportation by providing better equipment which will not require frequent repairs and which will, consequently, spend more time in actual service. In this connection the importance of standardization is emphasized.

To bring about a maximum use of freight-train cars, improvements must be made in terminal layouts, particularly freight-car yards. Frequency of train-tonnage revision should also be reduced as far as possible, and this can be done more readily when better freight yards are installed. The provision of sufficient capacity at all times to meet maximum prospective demands of traffic appears to be a sound policy, even though fixed charges and maintenance expenses are increased thereby. It is lack of adequate terminal facilities generally, and the permitting of cars to block yards and delay normal delivery, that causes equipment to stand still more than it should. In our efforts to expedite movement and to reduce cost we have increased the size and weight of locomotives and cars very considerably. Even under the present circumstances the possible axle load on the existing standard gage probably will not exceed 80,000 lb., while on some of the trackage of the country, especially in terminals, the permissible load per axle hardly exceeds 53,000 lb., and the heaviest A.R.A. standard journal provides a maximum load per axle of only 63,000 lb.

Terminal Expense

The problem of terminal expense is one of the vital questions before the railroads today. While some may be considering the increase of track capacity to meet the demand for quicker handling of less-than-carload freight, this can only result, in most cases, in increasing the storage capacity available through the use of freight cars.

Improvement can be further attained by developing a proper supply of cars and locomotives as needed, particularly by increasing the length of runs. The need of replacing smaller with larger power still exists, however, but with proper maintenance and rate of replacement there does not seem to be need for any large increase in the number of locomotives or freight cars. There should be proper anticipation of requirements for prompt movement, not only in equipment units but in roadway facilities to reduce unnecessary stops. Aside from peak-load periods, the tonnage does not increase rapidly. There remains the necessity of expediting movement the moment tonnage is offered, to reduce the cost and time of handling from loading point to final destination.

There is a possibility of movement of so-called less-than-car-load lots by motor trucks. This should not seriously affect carriers, inasmuch as short hauls involve such a high terminal expense that they are not profitable and railways will continue to carry long-haul products.

[1] General Superintendent of Motive Power, Chicago, Milwaukee and St. Paul Railway. Mem. A.S.M.E.

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Reduction in grades, elimination of curvature, the introduction of heavier rails, the use of larger freight-train cars and more powerful locomotives have all required a vast outlay of capital. They have somewhat reduced the proportion of operating costs to aggregate revenue, though the definite relation of the savings to the actual addition to fixed charges is still a problem. It is perfectly clear, however, that every substantial improvement in railway facilities ought to reduce the ratio of operating expenses, and to a smaller degree increase the fixed charges.

Problem of Slow Movement

Statistics show that freight cars travel about 30 miles in 24 hours, although they are generally moved in transit at a speed of not less than 20 miles per hour. If a car runs over 20 miles of track in an hour, it will cover 30 miles in one hour and thirty minutes, and the other 22 hours and 30 minutes of the 24 hours the car is evidently standing still, or being switched, or running empty. We sometimes hear that more unloading tracks at terminals and more cars and engines should be provided. We must emphasize the fact that systematic work on the part of the seven important subordinate officials must be obtained: the roundhouse foreman, car foreman, chief dispatcher, trainmaster, traveling engineer, yardmaster, and freight-house foreman. We need to have the most intelligent inspection, lubrication, and light repair work on locomotives and cars before each trip, and the latter should give maximum uninterrupted mileage. A breakdown of one engine or one car will delay the whole train, and a large number of derailments can be traced to carelessness on the part of the inspectors. All employees should perform their duties on schedule time, engines should be put through the house quickly for return trip, extraordinary delays between terminals should be eliminated, and delays to trains by switch engines should be avoided. The local officers need to detect the apparently insignificant things which impair efficiency, because railroad employees are prone to slight the apparently little things unless closely watched by their superiors.

The unit "average car-miles per car-day" was long used by railroads before it was adopted by the Interstate Commerce Commission in 1920. The method of determining this performance is to take both serviceable and unserviceable cars, divide them into the number of car-miles for the month and divide the result by the number of calendar days in the month. If the unserviceable cars, which are not making mileage, are excluded from the calculation, it will increase the car-miles per day by about 4 per cent. Even counting the serviceable cars in this calculation will not give the actual result, because so many cars which are standing at terminals and loading are not actually making mileage. It is reasonable to assume that cars actually running make from 75 to 80 miles per day. The data called for by the Interstate Commerce Commission, however, do express the use of cars on the line in relation to the number handled, and are therefore of value. For the country as a whole, the average per car-day for 1920 was 24.4 miles, and it indicates that the ownership of units has not increased at the same rate as the average miles per car-day and that the movement of tonnage has greatly improved.

Intensive Use of Cars

Full utilization of freight cars depends very much upon such factors as road, yard, shop, and terminal facilities, prompt handling of empty cars, the uninterrupted road movement of trains through the provision of passing tracks sufficiently long to meet modern tonnage requirements, on trains properly blocked so that they may run a maximum distance apart without interruption, on road and grade conditions such that freight-train movement at a proper rate of speed, without disturbance, can be carried on for a maximum

economical distance, on efficiency of train loading, dispatchment, etc. If new and overhauled cars are not of modern design, the object to be attained is not accomplished in the full sense of the word. To arrive at a maximum utilization with economical maintenance cost the officers in charge should have full knowledge of performance of such equipment, and should study obsolete-freight-car maintenance and shop and terminal facilities.

During 1925 the Car Service Division of the American Railway Association completed a study of the average loading of freight cars with various commodities carried by Class I railroads, with a comparison for 1923 and 1924. The information provides a means of determining to what extent the carrying capacity is employed by the various lines of industry and by the shipping public in various districts. The average of all cars loaded is influenced very greatly by the character of traffic, which changes not only from year to year, but during different seasons. Table 1 gives the number of tons in cars for carload freight originated (not including less-than-carload merchandise).

TABLE 1 NUMBER OF TONS IN CARS FOR CARLOAD FREIGHT ORIGINATED

District	Products of agriculture			Animals and products			Products of mines			Products of forests			Manufactures and miscellaneous			Grand total all carload traffic		
	1925	1924	1923	1925	1924	1923	1925	1924	1923	1925	1924	1923	1925	1924	1923	1925	1924	1923
Eastern	22.0	21.8	21.9	12.8	12.8	12.7	48.9	48.6	48.0	24.2	24.5	23.8	24.2	24.1	23.9	32.7	33.2	33.3
Allegheny	22.0	21.2	21.4	13.4	13.5	13.3	52.8	52.0	51.0	25.9	25.8	26.2	28.4	28.3	28.8	38.6	38.5	39.3
Pocahontas	16.6	16.5	17.7	12.0	11.6	11.8	57.4	57.4	56.7	27.3	27.3	27.6	26.1	26.5	27.6	51.8	50.7	49.5
Southern	16.4	16.5	16.9	11.7	11.8	11.6	48.1	47.6	47.0	25.4	25.5	26.1	24.4	24.1	24.1	31.5	31.1	31.5
Northwestern	30.9	31.6	30.9	11.3	11.2	11.3	50.5	49.2	32.4	32.4	32.5	32.3	27.7	27.2	27.5	35.2	34.2	35.3
Central West	25.7	27.6	26.6	11.5	11.5	11.4	46.9	46.7	46.4	30.1	30.2	30.7	26.7	26.7	26.1	30.7	30.7	30.5
Southwestern	20.8	22.1	21.8	11.8	11.5	11.7	43.2	43.3	43.0	26.2	26.4	27.3	26.4	26.3	26.7	28.3	28.4	28.4
Total all Districts	23.4	24 4	24.1	11.8	11.7	11.7	50.3	49.7	49.1	28.0	28.1	28.4	26.1	26.0	26.0	34.4	34.1	34.5

Table 2 is a commodity loading statement which shows some increases and some decreases and develops a number of large differences in the car tons.

A study of this information shows wide differences in the car loading as between railroads serving the same territory and covering specific commodities. For example, the loading of wheat in the section west of Chicago is 35 tons to the car on some roads, while others are obtaining as high as 44.9 tons, accounted for almost entirely by difference in car carrying capacity. Similar conditions can be observed with regard to practically every other commodity.

TABLE 2 COMMODITY CAR LOADINGS

Commodity	1925 Average, tons		1924 Average, tons		1923 Average, tons	
	Low	High	Low	High	Low	High
Wheat	27.6	47.8	30.0	50.1	31.5	44.2
Corn	16.0	44.3	15.0	45.1	13.8	42.3
Oats	14.0	37.5	13.0	36.6	12.6	35.9
Other grain	13.8	40.6	16.9	41.5	17.7	40.8
Flour and meal	9.8	31.7	9.7	30.5	9.8	30.4
Other mill products	10.8	26.2	10.4	27.2	9.6	26.1
Hay, straw, and alfalfa	8.5	14.3	8.5	14.2	8.4	13.7
Tobacco	8.9	15.6	8.9	15.7	9.5	14.7
Cotton	8.1	18.4	8.1	20.2	7.6	21.1
Cotton seed and prod. (exc. oil)	19.4	28.2	19.7	27.8	16.2	25.6
Citrus fruits	13.3	17.5	13.2	17.6	12.8	16.0
Other fresh fruits	9.8	19.0	10.1	18.0	10.6	18.7
Potatoes	13.3	20.5	9.7	21.5	13.4	20.7
Other fresh vegetables	8.8	21.6	9.2	24.0	9.0	23.0
Dried fruits and vegetables	15.1	29.0	14.9	29.5	14.8	30.5
Other agricultural prod.	12.1	47.1	12.6	48.0	12.6	46.9
Total products of agriculture	11.7	36.9	11.7	40.5	12.0	35.9

The performance of freight equipment may be measured roughly in terms of average miles per car-day, average load per car, and the relationship between loaded- and empty-car mileage. The reason for the increase in percentage of empty-car mileage does not result from the lack of a car unit that can be loaded in both directions with various classes of commodities, but is practically a result of the better performance on the part of the carriers. Just so long as the railroads continue to make an improvement in movement, they will show an increase in the percentage of empty mileage compared with periods when the movement has not been so prompt.

In the Interstate Commerce Commission's statistical report for 1920 it will be found that the average haul of all roads of Classes I and II considered as one system was 307.51 miles. The preliminary abstract for 1925 does not give a comparable figure, but from the basic data it may be worked out for Class I roads. The total revenue ton-miles were 413,823,173,484, and the originated tons were 1,247,243,183; thus by dividing we obtain an average haul of 331.79 miles. To be sure, the average haul per ton per railroad has declined in that period from 181.55 to 179.38, but on the whole, the unit first referred to is the more reliable for general purposes. Furthermore, the average load per car has not increased in the past five years.

The present year (1926) will probably show the greatest number of tons per loaded car for all Class I railroads, of any year, but this will be influenced very largely by the great increase in the production of mines. The average load per car, therefore, is a matter which is nearly beyond the control of the carrier, but the train performance is within such control, to a large extent.

The effective performance of freight cars is disclosed by the ratio of empty to loaded car-miles, which has run about 30 per cent in the past few years. It is necessarily high because of prompt handling of empties and to maintain a satisfactory car supply. The predominating movement of tonnage eastward and also, as long as this condition exists, the empty-car mileage will be considerably affected, as empty cars must be forwarded to loading points. By the work of the Car Service Division of the American Railway Association in the distribution, and movement of about 2,500,000 freight cars each day, shortages have practically disappeared. Car shortages have usually occurred because of:

1 Unusual and rapid increases in tonnage offered
2 Unexpected high loading peaks
3 Inequalities in volume of traffic
4 Inadequacy of terminals to take care of unusual heavy movements
5 Tendency to use cars as warehouses in spite of demurrage charges
6 Lack of industrial facilities for prompt loading and unloading of cars
7 Reconsignment abuses
8 Inadequacy of motive power
9 Individual carriers failing to equip themselves with a reasonable number of modern cars or an adequate number of cars of special type needed in certain industries
10 Unwillingness of shippers to load available cars to capacity
11 Weather conditions.

Train runs are on an arbitrary and specific basis, but cars are picked up en route, handled at terminals, set off between terminals, etc. Handling of cars on the road shows that the average speed of freight trains was 11.8 miles per hour in 1925 and the average mileage per car per day was 28.3, whereas if all cars could be handled from terminal to terminal without interruption at 20 miles per hour, in 8-hour runs this would mean 160 miles per day. The train speed of 11.8 miles per hour expresses delays en route due to intermediate switching, meeting trains, holding by signals, etc.

When train tonnage cannot be controlled definitely because of fluctuation in traffic volume, it still remains within the control of a railroad to increase train speed, as speed increase is equivalent to increase in gross ton-miles per train-hour. The lowest speed recorded for all Class I railroads in 1925 was 10.6 miles per hour, and the highest 15.9 miles per hour, or a difference of 50 per cent. The lower figure can be improved with no increase in the cost. Train speed should be construed to mean the average rate at which the mileage is produced from initial to final terminal. It is improved by eliminating elements such as:

(a) Too great a frequency of tonnage revision due to improper assignment of power
(b) Unbalanced regulation of tonnage movement in through and way freight trains, which should be corrected to

eliminate, as far as possible, delays due to set-outs and pick-ups, road switching, etc.

(c) Dispatching of trains to eliminate delays for train meets, standby losses of time on sidings, etc.

(d) Siding and passing track arrangements to prevent complete stops

(e) Spacing of trains, etc.

Terminal movement may be considered as a retarding factor under present operation and yard layouts should be improved to work cars through more rapidly. Longer locomotive and train runs constitute a move in the right direction, but should be further improved by proper terminal facilities, in conjunction with appropriate placement of sanding, coaling, and watering stations.

Improvements have been made in locomotive performance. Fuel consumption per thousand gross ton-miles has been reduced from 197 lb. in 1920 to 159 lb. in 1925, or 18 per cent. Better maintenance of air-brake equipment and education of trainmen have decreased payments for loss and damage to freight 69 per cent in the same period. Gross ton-miles per train-hour have improved likewise by reason of a slight increase in train speed and a marked increase in train tonnage, the latter brought about by better assembling and larger power units. Car shortages have disappeared because of better distribution and movement, but empty-car mileage, on account of characteristics of traffic, has remained about the same.

While freight car-miles per day have increased from 25.1 in 1920 to 28.3 in 1925, this is not to be considered an expression of ultimate utilization, because the character of maintenance and repair accorded has aided in availability. Freight-car heavy repairs become due in periods of about once every 8 or 10 years, whereas running repairs and inspection are a continuous necessity. The bad-order-car situation has improved in the last few years, and this applies to cars held out of service for heavy repairs. Cars requiring running repairs are usually not held more than a few days. Table 3 shows a comparison, on 100,000 individual units tabulated for a wide range of territory, of the car parts causing delays for repairs other than

TABLE 3 DELAYS CAUSED BY DEFECTIVE CAR PARTS

	Per cent of total
Air brakes	26.00
Body work	17.20
Door work	2.90
Roof	1.50
Safety appliances	5.00
Trucks	12.00
Draft gears and underframes	14.00
Wheels, general	13.40
Wheels, slid flat	1.50
Operating conditions	6.50
	100.00

periodical overhauling. Defective air brakes and bodies represent the largest cause for taking cars out of service. Next in order are draft gears, underframes, trucks, and wheels. The trouble with the body underframe is usually experienced with cars designed and built 8 to 10 years ago. The materials used in manufacture of wheels are a vital matter, as their renewal period is probably more frequent than necessary, considering that they have a life of only 60,000 miles. The better designs now being worked out with a view to reducing the frequency of attention to vital parts may add to the initial cost of the car, but this increase is very small in proportion to the resultant maintenance expense. Where 5 per cent or less of the cars are out of service for repairs the condition is considered normal, and this factor is not as great in the retardation of car movement as terminal handling.

Depreciation and Retirement Factors

Investment in equipment is a burden since carriers must make suitable charges for depreciation, and interest on the investment also has to be regarded covering the cars themselves as well as the cost for carrying investment in maintenance facilities. A study of the maintenance of the cars and the facilities needed for their upkeep shows that the cost per day per car to cover such features is about $1.00 or more. An increased use of freight cars is therefore highly desirable so as to minimize this burden. The question of the number of freight-car units necessary to handle the business has never been solved specifically. It would seem that the number of freight cars now in use is sufficient to handle an increase in business, provided there is an increase in utilization. However, there are many older and lighter cars still in existence of a design not fitted for heavy train movement, and there must be a proper rate of retirement of old and acquisition of new cars. If the character of loading can be improved thereby so as to increase the average load per car and the average miles per car-day, this should take care of a normal increase in traffic without increase in carrying units.

The problem of car utilization is not solved merely by low cost for repairs or large car supply. For instance, if 50-ton box cars will carry the prevailing grain tonnage, and if that represents a

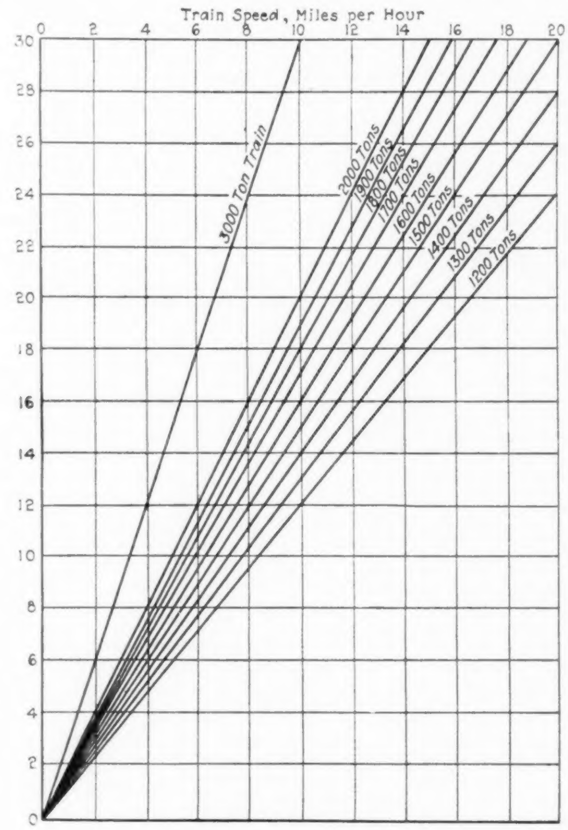


Fig. 1 Resultant Gross Ton-Miles per Train-Hour

(Train-miles per hour and gross tons per train as factors.)

majority of the business offered, such class of equipment should be employed to save track room as well as detailed maintenance and make it possible to retire two old cars for one modern unit. If an economical unit cost is to be attained constantly, it is necessary to consider the rate at which obsolete cars are retired and new ones acquired to maintain a proper complement of equipment. Take for instance the case of an administration applying the following rates of depreciation to their freight-train cars:

Period	Rate of depreciation
Prior to July 1, 1907	(Charged profit and loss)
July 1, 1907, to Dec. 31, 1912	$1^1/_2$ per cent
Jan. 1, 1913, to Dec. 31, 1915	1 per cent
Jan. 1, 1916, to Dec. 31, 1920	2 per cent

In such a case these rates would be used merely to charge a certain amount to operating expense each month, based on the above percentages applied to the total amount in the investment account for freight-train cars, and a corresponding credit would be made to "reserve for accrued depreciation," which is built up month by month. Under these circumstances, even where the highest rate of depreciation was charged at 2 per cent, it would involve a total life expectancy of 50 years (neglecting salvage) and the manner in which this would affect a railroad, if it was desired to retire a car at 20 years of age, would be:

Original cost	$1000
Salvage	200
	$800

From July 1, 1900 (date built) to July 1, 1907, or 84 months, the amount chargeable to profit and loss would be $\frac{84}{\text{Total, or 240 mo. (20 yr.)}} \times$ (cost to date less salvage equals profit and loss)	$186.00
From July 1, 1907, to Dec. 31, 1912, or $5^1/_2$ years, at $1^1/_2$ per cent on $1000 less salvage	66.00
From Jan. 1, 1913, to Dec. 31, 1914, or 2 years, at 1 per cent on $1000 less salvage	16.00
From Jan. 1, 1915, to Dec. 31, 1920, or 6 years, at 2 per cent on $1000 less salvage	96.00
Total	$364.00

This means that at time of retirement a road so situated would have remaining to charge to operating expenses under the retirement account the following:

Investment	$1000
Salvage recovered	200
Total	$800
Depreciation accounted for	364
Remaining to charge to operating expense	$436

Contrast this with another administration using a 6 per cent rate of depreciation; a parallel case would be as follows:

Original cost	$1000
Salvage	200
Profit and loss	$800
(84 ÷ 240 × $800)	$186
6 per cent for 13.5 years	648
Accumulated	$834
To be written out	800
Overdepreciated	$34

This makes a credit of $34 to operating expense and it might result in an administration's following such a practice to permit the only factors taking equipment out of service to be physical condition and obsolescence, and under such circumstances the maintenance expense might run 25 per cent below that of the first administration unless retirements were made regularly. In one case all charges would be made to depreciation; in the other case they would be split between depreciation and retirements, but both are in operating expense. In the first instance, in checking up the average age of cars held by various administrations, we find it ranging from 18 years to 35 years. It is important, therefore, to observe the policy of more frequent renewal and fewer heavy repairs or rebuilding, as it would seem to be more economical than extended life.

Aspects of Design

An analysis of 50-ton-car operation must consider two points. Can the greater loads they can carry be obtained? If so, what is the greater carrying capacity during a given period over and above the additional first cost, and the extra cost of hauling the extra dead load of the heavier cars? It is a question whether the results obtained from the 50-ton car in service will justify its extended employment in most localities in place of the 40-ton car, or whether the 50-ton car is suitable for a particular class of traffic in special territory. An intelligent analysis of this subject involves data for such factors as:

(*a*) First cost of car
(*b*) Capacity of car, cubic contents, and car weight
(*c*) Average load carried in tons
(*d*) Conditions which militate against full load
(*e*) Cost of maintenance
(*f*) Extra cost of hauling additional dead weight when moved with less than full capacity
(*g*) Extra cost for maintenance of permanent way, bridges, etc.

It would be valuable if a complete report could be had of the comparative results obtained by the use of 50-ton cars and others, covering a period of two or three years.

The Union Pacific and Southern Pacific, two of the most prominent railroad systems in the West, have at present in service thousands of 50-ton cars, and have had in service cars of this capacity for more than 20 years. Such equipment, as a rule, is loaded to a point reasonably near its capacity, for the entire route, and this unusually favorable condition of service gives the 50-ton car the place at once among the facilities that count for increased earnings. As further evidence of this, an enumeration of some of the various commodities handled at different points on the line and the quantity in percentage of the car capacity which enters into the general average attained is as follows:

Wheat	107.1 per cent
Corn	81.7 per cent
Barley	85.1 per cent
Other grain	100.4 per cent
Ore and bullion	114.6 per cent
Coal (largely in box cars)	84.0 per cent
Coal (open-top cars)	106.0 per cent
Gravel	109.0 per cent
Beets	101.4 per cent

This illustrates, on the other hand, the contention that there is a special field for the 40-ton car which the 50-ton car cannot invade without a positive loss. The field is one where such commodities as hay, merchandise, mill stuff, and miscellaneous products predominate and where they are moved to suit the shipper, regardless of the wish of the carrier. It is not possible to educate such shippers to secure traffic that will permit full-carload movement, at a specified time, which will compare with the handling of ore, coal, grain, and similar commodities which are regulated by the trainload rather than by the carload, and which are shipped at a time and in such quantities as not to require movements of less than the maximum trainload.

The freight-car mileage for 1925 was 26,729,831,000 miles; of this 35 per cent was empty mileage, indicating that many lines were operated when it was almost impossible to secure loading in both directions. While this is largely the case with roads that are essentially coal or ore lines, yet much of it is in the agricultural districts where the empty mileage is box-car equipment, handling an average of about 24 tons per loaded revenue car. This indicates that a general-utility car substantially built to meet interchange service with minimum dimensions of the A.R.A.'s standard box car, of a capacity not exceeding 80,000 lb., is from some points of view more desirable commercially and physically as a common standard than the 50-ton car.

It seems inconsistent that large lines should spend enormous sums of money on their permanent way and on motive power and equipment peculiarly adapted to their line and that then a large portion of this equipment should be diverted into a class of traffic and on to lines where the conditions are at considerable variance. While much of this modern heavy equipment is found on roads where its adaptability is questionable, we also find on the large trunk lines, which have adopted the modern heavy car, a great number of small, antiquated cars belonging to other lines. Many of these small cars were built years ago when the tractive power of freight engines averaged about 35,000 lb. This, together with their age, renders them scarcely safe for service in light trains on local runs, and dangerous when placed in modern heavy trains handled by large types of heavy freight engines. In case of accident, as a rule they are not only badly damaged but are the cause of destruction of the heavier cars with which they are intermixed, and the high cost of repairs on some lines can be traced to their retention in service.

Generally, coal cars returning empty to mines make the same number of empty miles as on the loaded haul, and there should be a saving in operation where larger cars are used. Furthermore, if there is a continued shortage of cars at mines in competitive territory during peak business, there would be a further gain in net revenue as a net result of whatever percentage of increased load was obtained. Assuming the net earnings per day, over and above all cost to handle, are one dollar on a smaller car, then with a larger car representing a 25 per cent increase in carrying capacity, this net would be increased to more than $1.25 a day. If the car requires ten days to make the round trip, the increased revenue would, at least, be more than $2.50 (cost does not vary directly with capacity

and the net saving will be more) for the round trip and would probably result in a substantial net return from the additional net revenue on the additional investment required to be made for the larger cars, provided the peak movement under these circumstances existed during 40 per cent of the yearly period.

One of the advantages given for steel underframe and steel-framed cars is that train resistance is less than with wooden cars. With a steel car, on account of its greater rigidity, there is less deflection in the bolsters, and the side bearings are not in contact under the maximum load, hence there is less flange friction and a lower traction. Secondly, the capacity of steel cars is much greater than that of wooden cars, and it has been found that train resistance for a given total tonnage increases with the number of cars required to equal that tonnage, owing to the greater area exposed to atmospheric resistance and the large number of wheels producing flange friction. With equal coupler clearance on straight track there should be no difference in the resistance of the wooden and steel cars, so far as the drawbars are concerned, but on the curves the rigidity of the steel draft rigging prevents the coupler from accommodating itself on the normal line of the pull, and if the clearance is too small the wheel flanges are forced against the rail, thus increasing the resistance. With the wooden car, however, the draft timbers are easily displaced or compressed, the bolts in the wooden draft attachment work to one side, and the whole rigging gives enough to provide a movement of the coupler equivalent to greater clearance and is sufficient to prevent undue flange friction.

For the utilization of each car to its fullest capacity, first steps must be taken at the origin of the traffic which, when west of Chicago, may be in isolated sections, not easy to supervise. Cars should be in proper condition with respect to wheels and air brakes before loading, because far too many refrigerator and oil-tank cars are delayed under load for wheel changes.

Freight cars, used in common under the A.R.A. car-service rules, are repaired on the road where the need for the repairs develops. The average freight car is at home not much more than one-half of the time. Obviously, with a common standard in interchanged traffic, each road would be required to carry a much smaller stock of repair parts, and there would be a reduction in repair time.

In car construction operating reliability is the first consideration. No feature in design, however efficient, and no economical maintenance practice will be tolerated if it impairs the ability of the car to function in regular train service.

Next to reliability in train operation comes the efficiency of design with respect to weight, cost, and structural stability. Net tons per carload seem to remain stationary in the face of improvement in practically all other factors.

Empty car-miles seem to increase by reason of better performance on the part of carriers. Where an improvement in other direction obtains, a decided increase in the percentage of empty mileage will result, and the reason for an increase in the percentage of empty mileage comes from prompter moving of empties, whereas when there was a low percentage of empty mileage the empties were standing still and there was a shortage of cars.

The only way a common-service box car could be provided would be to maintain all box cars at all times fit for the handling of the highest-class traffic that moves, though used for that traffic only a small percentage of the time. Many administrations find it economical to confine new and rebuilt box cars to the higher-class traffic and not permit them to get into the moving of stone, brick, tile, cement, lime, tar, and similar commodities. For cars used for automobile loading, a few trips may make such equipment unfit for flour, sugar, and other high-class loading, because the floors are stained with oil, cars are filled with nails, spikes, etc.

Many of the larger railroad systems have been following the principle of standardization for years, and the freight-car standards of these roads are the result of study over a series of years. It has been necessary, therefore, for the A.R.A., in formulating standards for general adoption, to give special thought to eliminating excess weight not justified by traffic and engineering requirements, because such added weight means not only a needless expense in first cost, but also in train operating expenses from an energy point of view. It is therefore important that the dead-weight proportion of a train shall be maintained at the lowest point consistent with reliability.

The proportioning of the longitudinal sills in the underframe for vertical load and end shocks is an important question. As regards the proper distribution of weight to each individual member, the Car Construction Committee of the A.R.A. has made exhaustive studies and cleared up this question.

In designing flat cars, concentrated load in the center of car must be considered. The present A.R.A. requirement for this class of equipment calls for an exceptionally heavy structure. The ballast car and coal hopper car also present a special problem as to load distribution, but in other types of cars a uniformly distributed load can be assumed, provided the design is based upon maximum loading conditions.

It is also a question whether the center sills should carry all of the load, or whether the side and center should each carry their portion, and, in the case of cars requiring sides for containing the lading, whether these sides should also act as girders and carry the greater portion of the load. Flat cars, for instance, are commonly designed with deep center sills, proportioned to carry most of the load, with rolled sections for side sills, figured as a continuous beam supported at the bolsters and cross-bearers, and carrying a small portion of the load distributed along the sides. Some administrations figure that the side sills should be made sufficiently strong to carry their portion of the load, thus necessitating fish-belly sills throughout. Such a requirement is sufficiently evident in normal interchange of cars designed to haul machinery, blocks of stone, etc., to make it a problem when selection in design is made. For steel gondola and such cars as require sides for containing lading, consisting of a web plate with top and bottom flange members, it is most economical to figure them as complete girders, proportioned to carry the greater portion of load, keeping in mind lateral stiffeners to prevent bulging. The carrying of the load on the side construction, because of its depth, makes an economical girder and works out cheapest, but does not apply to house-car equipment fitted with wooden superstructure. In this case the framing should not be depended upon on account of insufficient strength of wooden connections, of framing becoming loose as a result of wood drying out, and of tie rods imbedding themselves into the framework or otherwise losing their tension. It would apply, however, where a steel side sill at the bottom and steel side-plate construction at the top form an open truss between the bolsters.

The automatic coupler has eliminated many personal injuries, and provides a construction sufficiently strong to take care of the most severe service and prevent break-in-two. In providing and maintaining a suitable draft gear at the back of the coupler, impact blows must be absorbed in some manner. These should be taken by the draft gear and gradually transmitted to the component parts of the underframe, delaying the full effect of the blow until partially dissipated by the movement of the car. With the disappearance of wooden cars some train flexibility, due to the resilience of the underframing, has been lost.

The splicing of the center sills in front of the bolster and the use of separate draft sills to facilitate repairs have been the source of many arguments. One view is that if the center sills are made proportionally stronger at and between the bolsters than they are between the bolster and the end sills, any stress great enough to damage the draft sills could be easily reached and repaired. On the other hand, if the center sills were made in one continuous length from end to end of car, the cost of repairs, in a limited number of cases, would not be nearly as great as the additional expense of making the splice on all the cars at the time of building. With the use of a combination rear draft lug and bolster center casting there is no reason left for employing separate draft sills. In common with the practice followed by the A.R.A., the Chicago, Milwaukee & St. Paul Railway employs a combination rear draft lug and bolster center casting of the type shown in Fig. 2. Such construction makes it possible to deliver a maximum buffing shock with the least destruction to the car, because of the possibility of proper distribution to the center sills, bolster, and other longitudinal members of the car. Latest practice calls for integral center-sill construction from end to end of car, some administrations using a 5-ft. distance between the center line of the bolster and the face of the striking casting, in order to minimize the swing of the coupler on sharp curves and permit the shortest overall length in the case of hopper cars. Others prefer a $5^1/_2$-ft. distance to provide an ideal applica-

tion of the side-sill step and prevent interference with the opening of the journal-box lid when the sill step is placed centrally under the side ladder; also to take advantage of the reduction of stresses in the car structure, which is possible by reason of the greater overhang on the ends of the car.

The proportioning of the bolsters depends on the manner in which the vertical load is distributed and carried by the longitudinal members, thereby determining how much load is to be transmitted to the center plate through the bolster. The need for taking into account the raising of the car while under load when jacks are used at the extreme end of the body bolsters should not be overlooked. An important detail in bolster construction is the center filler between the center sills, shown in Fig. 3, located directly over the center plate; this must be designed to protect against fracture of the center plate and the possible tearing or bending of the bolster cover plate, thus allowing the side bearing clearance to be taken up, resulting in derailments of cars.

There has also been a remarkable development in brake apparatus

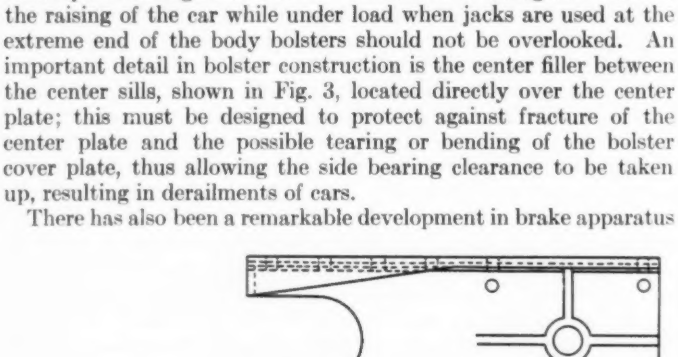


Fig. 2 Rear Draft Lug and Bolster Center Casting

for arresting the cars, either singly or in trains. Draft gears and brakes need to be systematically maintained with complete stenciled identification on each car showing date and place of last inspection and repair, a practice which has not yet been generally extended to the draft gears.

With regard to the permissible center of gravity of cars under load, $6^1/_2$ ft. from top of rail is about all that is safe for ordinary service; yet many of the large-sized hopper, automobile, and furniture cars are operating under load with centers of gravity in excess of 7 ft. This is the reason why many derailments and wrecks occur with cars 10 ft. high inside and loaded to the roof. The diagonal brace, which is usually placed in all underframes at the corners is extended by some designers from the ends of the center sill to the intersection of the side sill and bolster. Others extend the brace from corner to center sill at the bolster. The former arrangement relieves the center sill of a portion of the buffing shocks, transmitting them to the sides; also any cornering of the car sufficient to damage it to a considerable extent would be great enough to damage the brace if it extended from the corner of the car to the intersection of the center sill and bolster, and without the brace at the corner the underframe is much more easily repaired. On cars where push-pole pockets are used to a large extent, it is important that the brace be provided in the latter location to transmit the thrust to the center sill. The employment of roping staples located at or near the bolster has largely done away with push poles, and more cars are being pulled instead of pushed in spotting them.

Truck coil springs under 50- and 70-ton capacity cars often go solid under load and cause breakage. A truck spring has to work through a wide range of carrying capacity, namely, that of the light weight of the car body as a minimum, and this weight plus the full capacity of the car, which is generally equal to 5 or 6 times the light weight. While space restrictions are significant, the provision of a safe spring that will allow the car to remain on the track and will not permit the load to punish the track unnecessarily is important. Some roads are resorting to the addition of springs to give greater cushioning capacity; others are employing improved material or modifying the shape of the bar forming the coils to attain greater capacity and more travel. The bar of steel forming the spring should not be any larger than absolutely necessary so as to allow proper heat treatment. It is possible that, with increase in freight-train speeds, new designs will be required for greater safety, and to relieve the truck springs of the side-thrust action to which they are now subject.

The center-bearing truck shows superiority to the rigid wheelbase due to its continuous adjustment to the track, whether that be due to curvature or to defective maintenance. It also neutralizes the horizontal and vertical oscillations. The introduction of the center-bearing truck brought about the transfer of the journal bearings from the underframe of the car body to the truck frame. In this change of structure the load from the superimposed weight in most classes of cars is transmitted through the side sills to the center bearing by the introduction of the body bolster, which therefore becomes an important member of the underframe. For this reason it is important that the body bolster should be sufficiently rigid to transmit this load without sharing any part of the superimposed weight with the side bearings, the latter simply limiting the lateral swaying of the car body as in rounding curves. There is no tendency in the truck itself to resume its normal position after leaving a curve, except from the reaction of the flanges against the rail. If this reaction is neutralized by friction of the side bearings, the flanges may grind against the rail long after the curve has been passed. Reduction in flange wear reduces the amount of wear on the rail as well as train resistance, and therefore, when a car is at rest, the body bolster should sustain the entire weight without assistance from the side bearings.

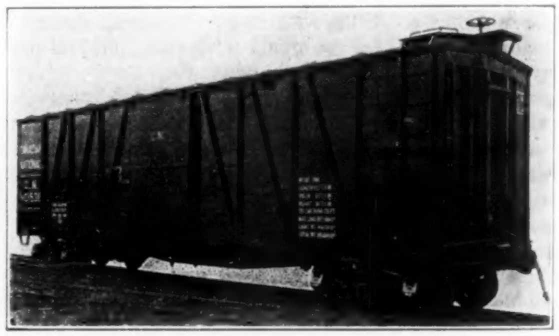


Fig. 3 Canadian National Box Car of Composite Construction. Capacity, 122,800 Lb.

The introduction of all-steel or steel-framed cars began when the first of the modern steel cars were built about 1897, although steel cars were built to a limited extent as far back as 1853. Taking the year 1907 as a base, the returns from thirty-six car-building concerns indicate 284,188 freight cars built, of which 72 per cent were of all-steel or steel-underframe construction, and this proportion emphasizes the rapidity with which the introduction of metal into freight-train cars took place from this period on.

The percentages of different features of construction used in typical cars built by six of the leading car-building companies in the country over the period 1921 to 1926, inclusive, are shown in Table 4, and typical examples of these cars are shown in Figs. 4 to 10.

The designing, up to the year 1912, of the modern all-steel and steel-framed car had been more or less left to the car builder, often under the supervision of railway mechanical officers. Later the larger systems took up the designing of their steel-car equipment on an extensive scale, furnishing builders with complete specifications, engineering analyses of all parts, detailed drawings, and bills of material. In the case of a railroad designing its own cars, it is possible to standardize its castings, forgings, and miscellaneous parts to a considerable extent. This may work out to the disadvantage of the car builder, as he, too, has standardized patterns which may differ from the railroad company's standard enough to necessitate new dies and patterns. These dies may never be employed on later orders, which means of course that the entire die and pattern cost must be borne by this particular order of cars. The number of complicated shapes should therefore be kept as low as possible. It is essential that all castings and such forgings as brake gear, draft gear, safety appliances, etc., should be standard-

ized as far as possible, in order to attain economical manufacture and maintenance. While the A.R.A. has accomplished admirable results in the way of standardizing car designs, truck parts, draft-gear parts, etc., this endeavor cannot be successful unless taken

TABLE 4 PERCENTAGES OF THE DIFFERENT FEATURES OF CONSTRUCTION USED IN CARS BUILT IN THE U. S. DURING THE PERIOD 1921 TO 1926 INCLUSIVE

Type of car	Box cars		Automobile cars		Gondola cars		Hopper cars	
Capacity in tons	40, 50, 55 & 60		40	50 & 55	50 & 55	70 & 75	50 & 55	70
Total number of cars analyzed	61822	51029	33941	17850	43428	9655	39829	32083
Kind of center sills:								
Channel	65	79	23	75	85	28	100	100
Fish belly	31	21	77	25	14	72	...	...
Wood	4	...	...	...	...	...	...	...
Miscellaneous	...	...	...	...	1	...	...	...
Total	100	100	100	100	100	100	100	100
Kind of trucks:								
Arch bar	16	16	10	...	8	...	27.3	...
Cast steel	75	82	90	87	90	100	62.4	100
Pressed steel	4	...	...	2	0.5	...	1.0	...
Miscellaneous	5	2	...	11	1.5	...	9.3	...
Total	100	100	100	100	100	100	100	100
Kind of wheels:								
Cast iron	99	99.5	100	88	7.4	...	78.4	1.0
Steel	1	0.5	...	...	91.0	100	12.3	94.4
Miscellaneous	...	...	...	12	1.6	...	9.3	4.6
Total	100	100	100	100	100	100	100	100
Width of side doors:								
5 ft., 0 in	1.8	...	...	...	...	...	...	...
5 ft., 5 1/2 in	1.3	...	...	...	...	...	...	...
5 ft., 6 in	7.0	...	...	...	...	...	...	...
5 ft., 11 in	2.4	...	...	...	...	...	...	...
6 ft., 0 in	83.6	86.0	...	...	...	...	...	...
6 ft., 2 in	...	14.0	...	...	...	...	...	...
7 ft., 0 in	2.2	...	...	...	...	...	...	...
7 ft., 6 in	...	...	3.0	...	...	...	...	...
9 ft., 8 1/2 in	...	...	...	2.8	...	...	...	...
9 ft., 9 3/4 in	...	...	...	5.8	...	...	...	...
10 ft., 0 in	1.7	...	81.0	80.2	...	...	...	...
10 ft., 0 3/8 in	...	...	4.0	...	...	...	...	...
10 ft., 1 7/16 in	...	...	...	1.2	...	...	...	...
10 ft., 1 3/4 in	...	...	2.0	...	...	...	...	...
10 ft., 2 in	...	...	...	1.5	...	...	...	...
10 ft., 3 3/8 in	...	...	2.0	...	...	...	...	...
10 ft., 5 3/4 in	...	...	5.0	2.7	...	...	...	...
10 ft., 6 in	...	...	3.0	5.8	...	...	...	...
None	...	...	...	...	100	100	100	100
Total	100	100	100	100	100	100	100	100
Size of end door:								
23 3/8 in. wide × 28 in. high	...	8	...	...	...	...	...	...
None	100	92	100	100	100	100	100	100
Total	100	100	100	100	100	100	100	100
Average light weight per car (lb.)	43753	45508	46402	48982	44351	51326	41262	50864
Average light weight per cu. ft. capacity (lb.)	15.82	14.76	14.31	14.09	26.06	31.36	22.15	20.43
Style of construction:								
All steel					42.5	82.0	83.9	100
S. U. & S. F.					14.5	2.0	9.5	...
Steel frame					17.0	13.0	...	...
S. U. & S. S.					1.0	2.0	...	...
Steel und.					25.0	...	3.8	...
Steel center sill					...	...	0.3	...
Comp. S. F. & S. S.					...	...	2.5	...
Total					100	100	100	100

seriously by the various administrations. Limiting stresses to be used in the design of cars need to be thoroughly understood, and the following recommendation is based upon exhaustive studies made with respect to A.R.A. standard car designs.

Unit Stresses.

STRUCTURAL STEEL

Tension .... 16,000 lb. per sq. in.

Compression for columns whose ratio of length to least radius of gyration is less than 40 .... 16,000 lb. per sq. in.

For columns whose ratio of length to least radius of gyration exceeds 40, determine the maximum unit compressive stress at the center of the column due to a direct load by means of the Rankine formula, fixed ends, transposed as follows:

$$S = \frac{PC}{A}$$

where S = maximum unit stress in lb. per sq. in. in a long column due to a direct load

P = direct compressive stress in lb.

A = area of section in sq. in.

$$C = 1 + \frac{1}{25{,}000}\left(\frac{L}{r}\right)^2$$

L = length of column in inches

r = least radius of gyration in inches.

For ends of columns, where the bending movement due to slenderness ratio is neglected .... 16,000 lb. per sq. in.

Shear .... 12,800 lb. per sq. in.

RIVETS

Shear .... 10,000 lb. per sq. in.

Bearing .... 20,000 lb. per sq. in.

WOOD

Tension .... 600 lb. per sq. in.

The car body should be designed to carry under service conditions

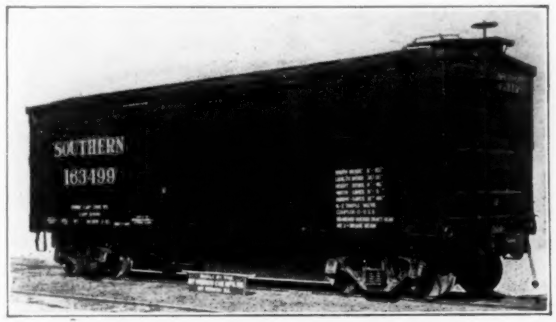


Fig. 4 Box Car for the Southern Railway, Equipped with Cast-Steel Trucks. Capacity, 80,000 Lb.

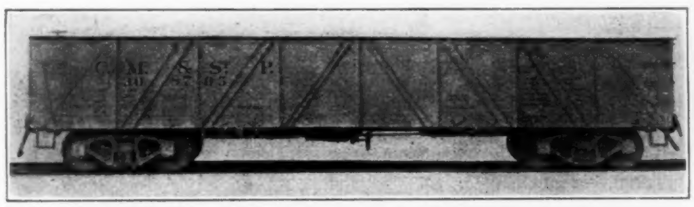


Fig. 5 Gondola Car of All-Steel Construction

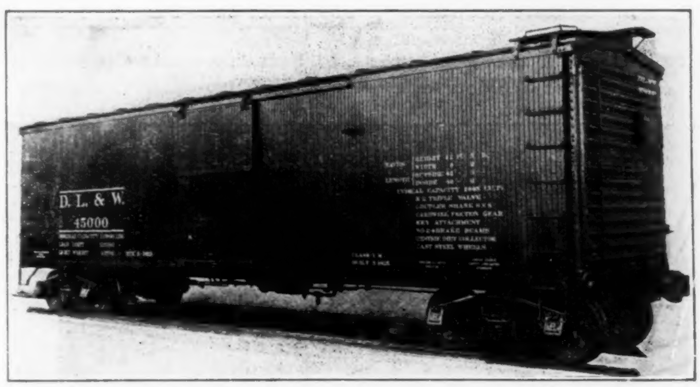


Fig. 6 Delaware, Lackawanna & Western Box Car Equipped with Cast-Steel Trucks. Capacity, 110,000 Lb.

the maximum rail load limit prescribed for capacity of car intended.

Center Sills should be designed to withstand

(*a*) An end load of 250,000 lb. applied on the back stop at the center line of draft

(*b*) Weight of center sill and attachments

(*c*) Vertical load reactions of floor planks.

Bolsters and Crossbearers should be designed to carry

(*a*) Total reactions from side sill for bolster, and center sills for crossbearer

(*b*) Weight of bolster or crossbearer attachments. Only the cover plates of bolsters and crossbearers should be considered as effective in resisting bending moment.

All connections should be designed for the maximum load to

which the member may be subject. Eccentricity effects should be either eliminated or secondary stresses caused by eccentric loads should be combined with the direct stresses.

Conclusions

Mechanical budget allowances are often controlled by officers other than those who are actually accountable for the results. Their decisions, respecting maintenance procedure, are based upon available funds or immediate earnings or prospective needs, to cope successfully with the present or future business and quite often

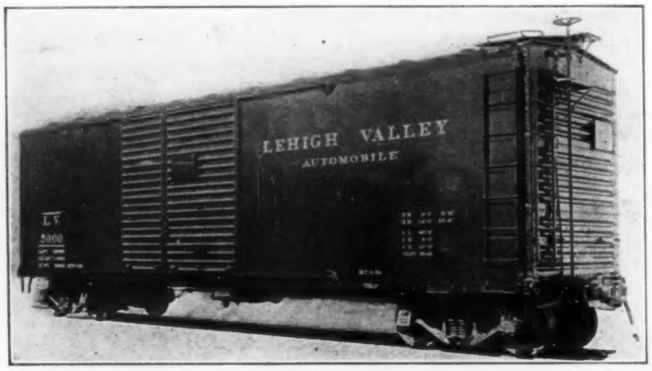


FIG. 7 AUTOMOBILE CAR EQUIPPED WITH STEEL DOORS AND ENDS. CAPACITY, 100,000 LB.

FIG. 8 CHICAGO, MILWAUKEE & ST. PAUL AUTOMOBILE CAR OF COMPOSITE CONSTRUCTION. CAPACITY, 80,000 LB.

FIG. 9 COMPOSITE AUTOMOBILE CAR FOR THE TEXAS & PACIFIC. CAPACITY, 80,000 LB.

neglect adequate consideration for economies for steady employment. Those who immediately direct should be cautious of the programs governing the handling of the work, and the time rate of output, so that the facilities may be loaded to an economical range of working. The budget of requirements should be worked out by forecast, plus experience and adjustments. A yearly allotment should be worked out, the same being based on a policy of procedure covering a term of years. Estimates should be made in advance for each month, and the various items tabulated on a budget sheet which can accommodate as many divisions of the work as are required. The principle of budgeting has regard for the advice which must be given the purchasing and stores department in advance so they can make the material supply coincide with a policy of steady employment of man-power.

The following topical suggestions are offered in closing:

(*a*) Railroads should systematically consider the current requirements of the service as they become increasingly apparent in view of enlargements in traffic and the changing conditions of operation.

(*b*) Maintenance policies need to be formulated far in advance, in order to maintain and turn over a proper number of cars by classes, also to employ a least complement of facilities and labor force regularly to keep the entire plant structure working efficiently.

(*c*) Adherence to a 20- to 25-year life for freight-train cars with an annual depreciation rate to coincide with whatever figure is used and provide for suitable and current replacement.

(*d*) Railroads should procure freight-train cars embodying design fundamentals recommended by the A.R.A. and of minimum weight consistent with traffic and engineering considerations.

(*e*) Should give constant thought to the fact that freight-train cars should be built interchangeably between roads to lessen first

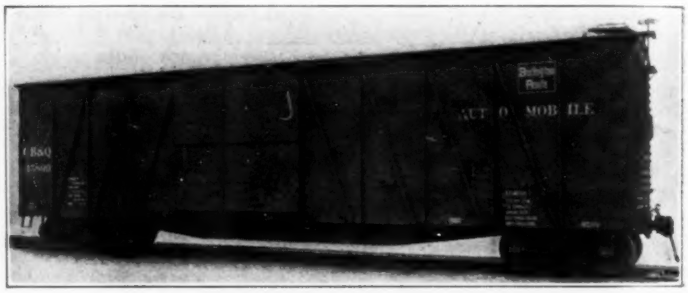


FIG. 10 AUTOMOBILE CAR FOR THE CHICAGO, BURLINGTON & QUINCY WITH FISH-BELLY CENTER SILLS. CAPACITY, 100,000 LB.

cost and improve current maintenance when cars are off line, and also to avoid delay by special material when needing repairs.

(*f*) Special classes of cars should not be built unless justified by actual traffic and operating experience factors.

Discussion at Railroad Session

Balancing Factors in the Use and Obligations Covering Ownership of Freight-Train Cars

W. E. SYMONS,[1] to emphasize, the importance of coöperation in the problem outlined by the author, Mr. Sillcox, presented certain fundamental features in Table 5.

While the concrete examples by the author on depreciation and retirement factors illustrated the points mentioned, a tabulated

TABLE 5 RAILWAYS AS A FACTOR IN NATIONAL LIFE

Total investment in U. S. railways (approx.)	$25,000,000,000
Income from operation (1925)	$6,239,353,447
Income from freight (1925)	$4,596,952,895
Average freight income per day	$12,594,336
Average freight income per hour	$524,764
Total number of freight cars	2,407,000
Total number of freight cars (less work cars and cars under repair, 275,000)	2,132,000
Average earning per car per year	$2,156
Cost of repairs (approx.)	$385,000,000
Average per unit (approx.)	$160
Number of security holders in U. S. railways (approx.)	2,000,000
Held by banks and insurance companies (approx.)	$3,000,000,000
Citizens either served, or affected by, and who should be interested in, this problem (approx.)	117,000,000

display of present practice on a number of leading railways might be of value in securing greater standardization, and adding to the reliability of reports of operation. Such a tabulation was that given in Table 6, from which it would be seen that on fifteen of the largest railway systems in this country the theoretical life of equipment was as follows: Locomotives from 22 to 50 years; passenger cars, from 22 to 66 years; freight cars, 22 to 50 years; work equipment, from 20 to 50 years.

The Transportation Act of 1920 had directed the Interstate Commerce Commission to fix uniform rates of equipment depreciation to be used by all carriers, and during Federal control the Director-

[1] Consulting Engineer and Associate Editor, *Railway and Locomotive Engineering*, New York, N. Y. Mem. A.S.M.E.

TABLE 6 RATES OF DEPRECIATION

Railway company	Locomotives, per cent	Passenger cars, per cent	Freight cars, per cent	Work equipment, per cent
One	4.5	4.5	4.5	4.5
Two	3	2	3	2
Three	3	3	4	5
Four	2.5	2.5	3	2.5
Five	2	2	2	2
Six	4.5	2.5	5	5
Seven	3	3	4	4
Eight	2	1.5	2	2
Nine	2.5	2.5	2.5	2.5
Ten	3.5	3.5	4	4
Eleven	4	4	4	4
Twelve	4	4	4	4
Thirteen	3	3	3	4
Fourteen	2	2	2.75	2.75
Fifteen	3.44	3.73	3.31	4.75
Average	3.13	2.88	3.54	3.4

General had issued an order in May, 1919, that all carriers during the period of control should depreciate equipment placed in service after December 31, 1917, at the rate of $4^1/_2$ per cent per year. A number of lines had combined to use this rate, and depreciation charges were now more uniform than in prewar years.

There was such a wide range of difference in the apparent operating efficiency of two lines, fairly comparable throughout except as to the amount of depreciation charges taken up and charged to operating expenses each month. This one feature alone had much effect on the integrity of operating statistics, particularly when used for comparative purposes. It might be said that on lines other than those shown in the tabulation fluctuations had ranged from 1 to 6 per cent, and until the Commission should specify an exact rate to be charged on account of depreciation of equipment, desired results would not be attained. Increased mileage per day, and increased tons per car, as well as improved train movement, were all important features, and improvements in these factors would tend to greater efficiency, while the subdivision of car parts causing delays for repairs, given in per cent of contributing cause, should be given consideration.

As a result of the splendid work of the American Railway Association and other bodies, and the great help rendered by railway officers, there had been almost a reversal of the former antagonistic feeling toward railways. Today the railways were conceded to have some rights, and were given a reasonably fair deal in almost all matters except the use of freight cars. Thousands of shippers were still using loaded freight cars consigned to them as auxiliaries to their warehouses or for storage purposes. It had been estimated that from 150,000 to 200,000 freight cars were thus either being used for purposes other than intended, or held under full load awaiting a change in market price of some commodity, or for some other reason foreign to transportation. A freight car was an integral part of the physical property of a complete transportation unit, and all property intended for transportation service should be used for this purpose only.

The Use of High Steam Pressure in Locomotives

Clement F. Street[2] emphasized that we had traveled a long way since a locomotive consisted of a boiler, cylinders, valve gear, frames and drivers, and the attachments of an air pump and injector. It was now one of the most complicated structures in existence. Further improvements were a job for the designer and not for the inventor.

The figures of gain in efficiencies given in Table 1 of Messrs. Schmidt and Snodgrass' paper, when plotted, produced an even and regular curve, but these figures related to Rankine-cycle efficiencies alone. If each of the many things which had a bearing on the subject could be plotted in a curve combined with this curve, there would be a radical change in its form.

A. H. Fetters[3] stated that at Cassel, Germany, he had examined the ultra-high-pressure locomotive built by Henschel & Sohn. This was not an entirely new structure but an alteration of an existing locomotive, providing for the alteration of existing locomotive power from standard to ultra-high-pressure. That such a change could be made was a great advantage. The ultra-high-pressure locomotive, in a series of extensive road tests, had shown, in addition to the anticipated thermal economy, an unexpected increase in boiler-performance economy, the boiler at certain ratings showing an efficiency as high as 80 per cent. There were many localities in which the quality of the water was such that undoubtedly there would be little or no trouble experienced with the high-pressure boiler, and better sources of water and water treatment would result in extension of this service into territories not at present suited.

The conviction of the engineers developing this high-pressure locomotive was that it was best to adopt an ultra-high pressure from the very start. In the high-pressure locomotive now being developed by Dr. Buchli at the Swiss Locomotive Works a water-tube boiler of novel design was employed, with one direct pressure instead of three, the pressure also being in the neighborhood of 800 lb. The superheated steam at this pressure was fed directly to a small three-cylinder high-pressure steam engine located detachably at the front end of the locomotive, the high-pressure cylinder being in the center and exhausting to the two outside low-pressure cylinders. Poppet valves were used for steam admission and the exhaust was at the center of the cylinder through ports in the cylinder wall uncovered by the piston. Thus the uniflow principle was introduced in combination with high-pressure superheated steam. The engine was entirely enclosed, similar to an automobile motor, and ran at a very much higher speed than the average direct-connected cylinder engine. The engine was designed for 1000 to 1200 r.p.m. and was geared down to a jackshaft with outside cranks, permitting side-rod connection to the driving wheels as in electric-locomotive practice. Some very substantial economies from the high-pressure boiler in connection with this high-speed engine were obtained.

Charles B. Page,[4] reported that European executives, railroad engineers, and locomotive manufacturers were of the opinion that high pressure for locomotives was correct in principle and that its use commercially was right at hand. Visiting Cassel, Germany, on October 30, 1926, he had witnessed trials of the Schmidt-Henschel ultra-high-pressure locomotive described in the paper under discussion, and had gained the distinct impression that the initial demonstrations of this locomotive had shown a tremendous advance in motive-power design. In German railway circles it was understood that Schwartz & Co.'s Berlin Machine Works were developing a 2500-hp. locomotive using the Loeffler system. The working pressure was to be 1500 lb., utilized first in a high-pressure cylinder and expanded a second time in two lows after reheating. The Krupp Works in Essen had finished their development of the 2000-hp. Zoelly type turbo-condensing locomotive, a description of which had already been published. On November 2, 1926, this locomotive was in Berlin and in the hands of the German Railways for final test. Krupp's plans for a second locomotive of the same general type but with a working pressure of 60 atmospheres were now being completed. The Swiss Locomotive & Machine Co., Winterthur, Switzerland, had built and were now testing a new system for locomotives employing a working pressure of 60 atmospheres. The firm of J. A. Maffei, having completed their first turbo-condensing locomotive of 2000 hp. were now engaged in the development of plans for a similar locomotive but for even higher pressures than proposed by Schwartz & Co. In stationary and marine practice, two notable developments were of interest. In Berlin, the Siemens-Schuckert Works, which some time ago purchased all rights to the Benson superpressure power, were now erecting a boiler on this system having a capacity of 60,000 lb. steam per hour at a boiler pressure of 3200 lb. Escher Wyss & Co. were building the turbine for this plant. The nozzle pressure was to be 2560 lb. In the marine field, the *King George V*, put into service in the summer of 1926 on the river Clyde and built jointly by Parsons Marine Steam Turbine Co., Ltd., Messrs. Denny & Bros., Ltd., and Messrs. Yarrow & Co., had proved that high working pressures—550 lb. at a total temperature of 750 deg.—were practical. The *King George V* had met every expectation, and Sir Charles Parsons' comparative estimate of operating costs as between a Diesel-powered cargo vessel of 5000 hp. and a steamer of the same capacity, with power plant patterned after that of the *King George V* was entirely favorable to the steam plant.

Lawford H. Fry,[5] discussing the figures in Table 1, pointed out that the calculations as to the efficiency of increased pressures were

[2] Greenwich, Conn. Mem. A.S.M.E.

[3] Mechanical Engineer, Union Pacific Railroad Company, Omaha, Neb.

[4] Manager, Steamotor Company, Chicago, Ill. Jun. A.S.M.E.

[5] Metallurgical Engineer, Standard Steel Works Co., Burnham, Pa. Mem. A.S.M.E.

based on a constant superheat of 250 deg. so that an increase in pressure was accompanied by an increase in steam temperature and also by an increase in the total heat of the steam. The increases in efficiency were therefore not necessarily due alone to the increases in pressure. Unless a radical change were made in existing locomotive boiler designs, an increase in steam temperature would not be obtained or would represent a considerable loss in boiler efficiency. It therefore appeared preferable to base comparisons not on uniform superheat, but on uniform steam temperature, say, 650 deg. fahr. This would give about 260 deg. superheat at 200 lb. and about 175 deg. superheat at 600 lb. per sq. in. Also the total heat would fall off with increasing pressure, being approximately 1340 B.t.u. for 200 lb. and 1325 B.t.u. for 600 lb. per sq. in. The efficiency shown by the Rankine cycle under these conditions was about 30 per cent better for 600 lb. than for 200 lb. per sq. in. Mr. Fry suggested, however, that the Rankine cycle was not a good basis for comparing locomotive-cylinder efficiencies. It assumed that the steam was expanded adiabatically all the way down to the exhaust pressure, taken in the paper to be 20 lb. per sq. in. abs. With steam of 200 lb. per sq. in. this meant an expansion of about $6^1/_2$ times and with steam of 600 lb. per sq. in. an expansion of nearly 17 times. These did not represent conditions realizable in any existing reciprocating-locomotive design. With single-expansion cylinders, expansions up to 3 or $3^1/_2$ were usual, while with compound cylinders the expansion could be carried to 4 or 5. For comparing locomotive-cylinder efficiencies the ideal cycle should be based on admission at boiler pressure, adiabatic expansion to a definite number of expansions, say, three, then release to exhaust pressure and exhaust at that pressure. On the basis of such a cycle the gain shown by high pressures would be very much less than those shown by the unattainable Rankine cycle with its impossibly high expansions for high pressures. As pressures were increased, it became important to aim at an increase in the expansion of the steam.

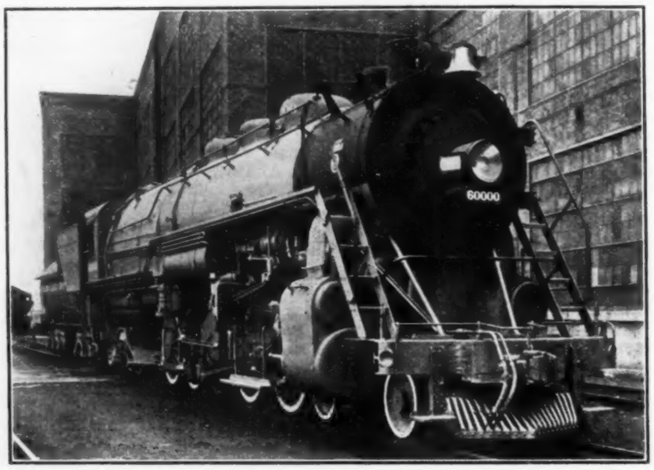


Fig. 11 Front View of Baldwin Three-Cylinder-Compound 4-10-2-Type Locomotive

For those desiring to make a further study of the thermodynamics involved attention was called to a paper on The Economic Value of Increased Steam Pressure, by H. L. Guy, read recently before the Northwestern Branch of the Institution of Mechanical Engineers, and reported in *Engineering*, November 9, 1926. Pressures of 240 and 250 lb. per sq. in. were, as the authors pointed out, firmly established in American practice. In fact the Pennsylvania Railroad had now in operation over 600 2-10-0-type and 200 4-8-2-type locomotives using 250 lb. per sq. in. and to the water-tube firebox locomotives must be added a 4-10-2-type three-cylinder compound with 350 lb. per sq. in. built as an experiment by The Baldwin Locomotive Works. Actual measurements indicated that on the Pennsylvania locomotives the increase in pressure from 200 to 250 lb. per sq. in. gave a decrease of about 9 per cent in steam consumption, and that an increase to 350 lb. per sq. in. would give a further decrease of about 10 per cent. The gains in efficiency and the possibility of securing a large tractive effort with cylinders of moderate size made pressures of 250 to 400 lb. per sq. in. worthy of careful consideration by locomotive designers, but if pressures in excess of 250 lb. per sq. in. were used it seemed desirable to eliminate the use of staybolts in the boiler and to adopt a cylinder design capable of giving a high degree of expansion.

The Baldwin Locomotive Works' 350-lb. per sq. in. three-cylinder compound 4-10-2-type locomotive with water-tube firebox was illustrated in Figs. 11 to 14. The main dimensions of this engine were as follows:

Cylinders:	
High pressure (1) inside	27 in. by 32 in.
Low pressure (2) outside	27 in. by 32 in.
Driving-wheel diameter	$63^1/_2$ in.
Heating surface:	
Firebox and arch tubes	772 sq. ft.
Flues and tubes	4420 sq. ft.
Total evaporative	5192 sq. ft.
Superheater type A	1357 sq. ft.
Grate area	82.5 sq. ft.
Weight on driving wheels	338,400 lb.
Weight of locomotive, total	457,500 lb.
Rated tractive force (compound)	82,500 lb.

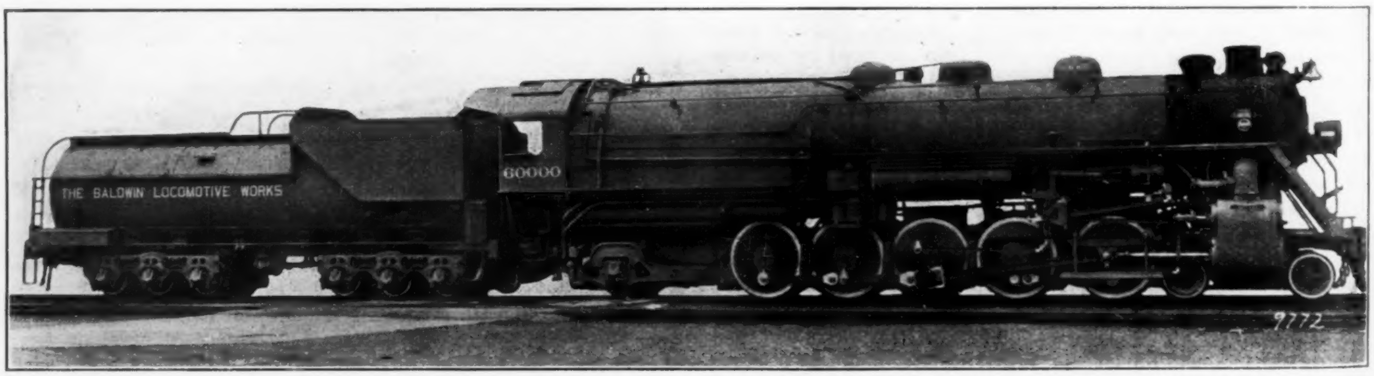


Fig. 12 Longitudinal View of Baldwin Three-Cylinder-Compound 4-10-2-Type Locomotive

The general appearance of the locomotive differed in no way from that of a locomotive of the usual construction. The front view, Fig. 12, showed the three cylinders, which were controlled by three individual valve motions. The cylinders were compounded. The steam after passing through the middle cylinder was exhausted through a receiver in the cylinder saddle to the two outside cylinders. The boiler pressure was 350 lb., and to carry this pressure satisfactorily the firebox was of a modified Brotan design. Fig. 13 showed the outside appearance of the complete firebox before the firebrick sheathing was applied, and Fig. 14 showed the box with one side removed showing the arch tubes carrying the firebox arch which separated the front part of the box from the rear. The grate was applied back of the arch and the front portion of the firebox formed a combustion chamber. A few advance figures were available from tests at the P.R.R. Locomotive Testing Plant at Altoona.

Fig. 15 showed the power and efficiency of the boiler. An equivalent evaporation of 85,000 lb. per hour was attained with about 11,900 lb. of dry coal fired per hour. At this maximum rate of firing

the boiler efficiency was about 52 per cent. The results did not differ from those to be obtained from a boiler of conventional design. This was expected, as the water-tube construction was adopted for the purpose of carrying the high pressure and not with the idea that it would give greater efficiency.

Fig. 16 showed the water rate per i.hp. in relation to the horsepower developed. This showed that in two tests the engine indicated 4500 hp. The water rate remained extremely uniform for all horsepowers between 1500 and 4500, and was little affected by variations in speed and cut-off. At speeds from 15 to 37.5 m.p.h. and cut-offs from 50 to 80 per cent in the high-pressure cylinder the steam per i.hp-hr. varied from 14.2 to 15.4 lb. In full gear with 90 per cent cut-off in the high-pressure cylinder the water rate was 16.3 lb. at 15 m.p.h. and 16.6 lb. at 22.5 m.p.h. The dry coal per indicated hp-hr., as shown by Fig. 17, ran from 1.9 lb. at low powers up to 2.7 lb. at 4500 hp. The results in road service confirmed those obtained on the test plant, and no serious operating troubles had developed.

W. A. Newman[6] pointed out that the Canadian Pacific Railway was a firm believer in the benefits of higher steam pressures; in fact,

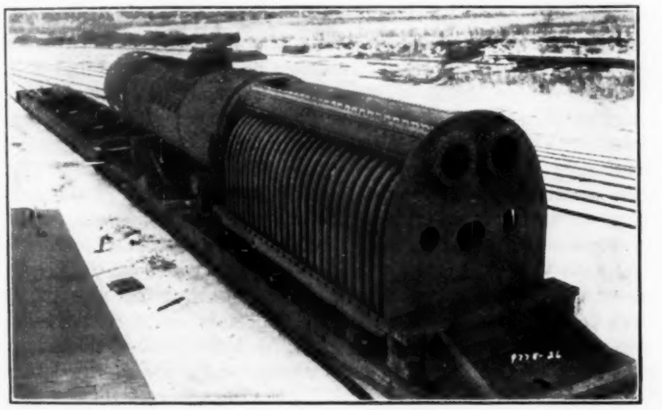


Fig. 13 Boiler and Water-Tube Firebox of Locomotive Shown in Figs. 11 and 12

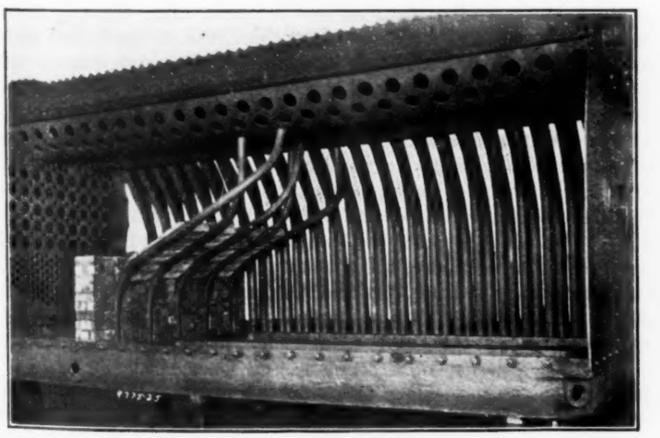


Fig. 14 Interior View of Water-Tube Firebox

during the present year they had departed from their conventional design of 200 lb. boiler pressure and had constructed forty-four locomotives carrying a working steam pressure of 250 lb. per sq. in. These locomotives were equipped with feedwater heaters and a front-end throttle, and all auxiliaries excepting the lubricator and inspirator were operated with superheated steam. Rather than adding to the weight of the boiler-shell plates by increasing the thickness by 25 per cent, they had pioneered the production of nickel-steel boiler plate having a minimum tensile strength of 70,000 lb., a minimum elongation of 20 per cent, and a minimum reduction of area of 50 per cent. All forty-four locomotives were constructed with this boiler plate and from the standpoint of surface appearance, uniformity of physical properties, and handling in the shop, the development had been highly successful. Just as alloy steels had helped to solve some of their problems in regard to weight of reciprocating parts, so special steels and non-ferrous metals would also help to solve the problems incidental to higher steam

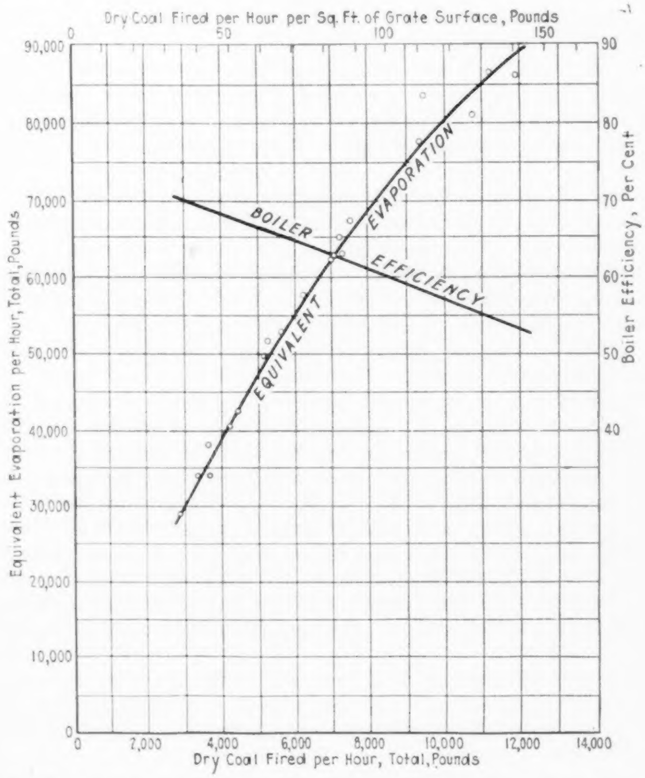


Fig. 15 Evaporation and Boiler Efficiency of Locomotive No. 60,000

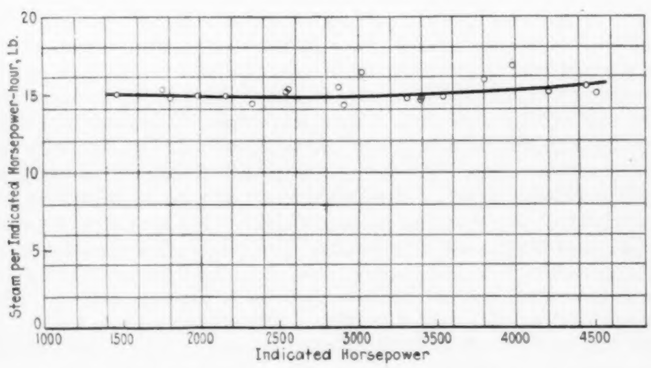


Fig. 16 Water Rate per Indicated Horsepower-Hour, Locomotive No. 60,000

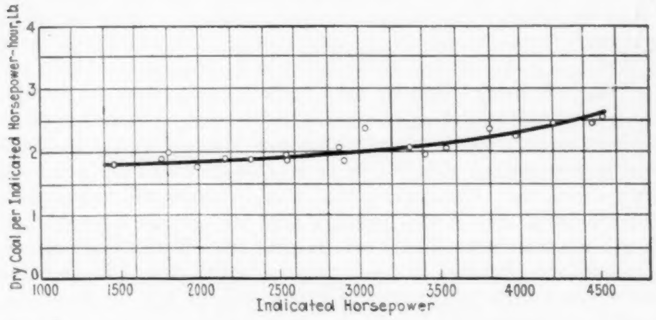


Fig. 17 Coal Rate per Indicated Horsepower-Hour, Locomotive No. 60,000

pressures. Limited experience had shown that their 250-lb-pressure locomotives were easier on coal and water, accelerated faster, were rather freer running, and were capable of somewhat higher speeds than sister engines operating at 200 lb. pressure. Unques-

[6] Mechanical Engineer, Canadian Pacific Railway Co., Montreal, Canada.

tionably still higher steam pressures would become the practice for high-capacity locomotives in the future, and while there had been considerable progress made with experimental types of boilers for higher pressures, there was a very great deal to be accomplished as yet.

Harold Anderson[7] in a written discussion stated that the Ljungström turbine-driven locomotive, which was described in *Engineering* (London), July 21, 1922, carried 300 lb., which was slightly higher than the 285 lb. mentioned as highest pressure by the authors. The ultra-high-pressure locomotive built by the German State Railways employed three different pressures, but no reason was given for this unusual design. It seemed probable that the indirect heating of the 850-lb. boiler was an attempt to minimize scaling. The benefits derived from the 200-lb. boiler seemed rather problematical, as its use reduced the advantages obtainable from a straight high-pressure cycle. He asked whether it would not be possible to substitute an economizer section for this low-pressure boiler, as this would result in a more efficient installation.

James M. Taggart[8] wrote that the ideal locomotive would be one equipped with a complete water-tube boiler, probably of the explosive type, with water-tube furnace walls, a suitable superheater, economizer sections, air preheater, equipment for burning pulverized coal, engines on the uniflow principle, feedwater heating, and air-cooled condensers. To install all the above apparatus on a locomotive and tender might appear at first glance impracticable. The advantages of the inclusion were apparent, however, to any one familiar with present power-plant practice. A greater combustion intensity could be maintained with pulverized coal than with any other form of coal burning. For locomotives reduction in furnace volume as well as the resulting reduction in labor were of special value.

To absorb the radiant heat from such a high intensity of combustion without serious burning of tubes would require an exceptionally clean feedwater and special high-temperature steel. The condenser would tend to assure a cleaner feed than usual and the make-up would have to be a treated water. The success in rolling high-chromium-steel tubes provided a material suitable for the water tubes exposed to the furnace radiation. In addition portions of these tubes as well as the superheater surface might be covered with some of the special refractories such as carborundum. The use of pulverized coal and the explosive type of boiler would give quick steaming and instant response to a change in loading. Economizer sections and an air heater would allow for a minimum of boiler heating surface and a higher economy than could be attained with boiler surface alone. The use of the uniflow principle in the engine cylinders would give the same advantages as compounding without as much complication, and provide a higher economy for changeable loads, and for low back pressures. Practice with automobile air-cooled radiators and the condensers of steam automobiles showed that air-cooled surface condensers were a possible solution. It would not pay to install a condenser of sufficient surface to give a low vacuum for all conditions. During periods a circulating fan would undoubtedly be necessary. The main advantage of the condenser would be to assist in maintaining a clean feedwater and to eliminate the necessity of carrying a heavy load of water. Oil would necessarily be present in the feedwater. With the high-temperature steel tubes suggested a small amount of oil if of a good grade for the service might not be dangerous. If found necessary, filtering could be used, with a renewal of the filtering material at the end of each run. The best results that had been attained even under tests with the combination water- and fire-tube boilers treated of in the paper was about 2.3 to 2.5 lb. of coal per drawbar hp. Considering the stand-by losses, the uncertainty of hand firing, etc., it was probable that average results would not show lower than 4 lb. of coal per drawbar hp. With the equipment suggested an efficiency at least twice as great should be possible. For a locomotive containing the features proposed, the condenser would probably need to be in the front. The tender carrying the make-up and coal would occupy much less volume. There would be no need of the room now required for hand firing. The reduction in total weights due to the lighter boiler, smaller-size cylinders, and smaller weight of water and coal would probably be fully equal to the added weights of the economizer, air-heater, and condenser.

A. I. Lipetz[9] wrote that the advantages of higher pressures had been realized for years, and if it had not been for the difficulties involved in construction and maintenance of the boilers at those pressures, we should have had them long ago. When the compound locomotive, which had caused a previous rise in boiler pressures, was supplanted by the superheated locomotive and the pressures were temporarily lowered, the innovation was welcomed by many railroad operators who were eager to reduce their boiler-maintenance expenses. However, it did not last long, as the call for larger power revived the tendency of increasing boiler pressures, although the rise did not go on very rapidly. The difficulties due to high pressures, such as maintenance of valves, pipes, joints, etc., had been practically overcome in stationary service, and would also be overcome in locomotive practice. There remained, however, the suitability of the high-pressure water-tube boiler to the peculiar conditions of locomotive service which he thought merited separate consideration.

The multi-fire-tube boiler of the early locomotive was something with which the locomotive designer would not willingly part, as experience had taught him that this boiler was not only reliable, low in first cost, and compact, but also insured great evaporation capacity in the small space available on a locomotive and within the permissible limits of weight. Besides, it had the great advantage of heat-storing capacity, which was necessary in view of the constant variation in the load factor of a locomotive. Even in stationary plants, if the load factor fluctuated considerably, it was now customary to add a heat accumulator, usually of the Ruths type, to high-pressure boilers. An attempt was made by Robert in France to depart radically from the conventional locomotive-boiler type; he built in 1904 the first and only water-tube boiler for a locomotive, without any tubular part at all, but this attempt met with very little success, and had never been repeated.[10] All further designs, those of Brotan, McClellon, Muhlfeld, and of the Schmidt Company of Germany, had the characteristic longitudinal barrel with fire tubes inside, thus retaining the heat-storage feature of the ordinary locomotive boiler. The barrel design was not easily adaptable to high pressures; nevertheless we had already in this country two locomotives with boilers of this type carrying 350 lb. gage pressure, and a third locomotive with even higher pressure was now under construction. The thickness of the barrel plates was already approaching the safe limit of manipulation by cold bending; 400 lb. represented the highest pressure for the type of boiler in which the barrel portion was subjected to the full pressure of the steam, unless we went to special steel for the barrel plates. Design would probably crystallize into a combination of a water-tube firebox with a barrel fire-tube portion, embodying the best features of the McClellon and Muhlfeld boilers, provided that the higher cost of the boiler and its maintenance due to possible scaling, etc., did not overbalance the economy in fuel; even then we should still have the increase in power of the locomotive of a given weight as a result of lesser steam consumption, although possibly without much saving per unit of power.

To make full use of the increase in ideal efficiency of higher pressures, it was necessary to maintain at least the same efficiency ratio. H. O. Hartmann's tests, referred to in the paper, had shown that this was possible, if compounding was resorted to. It was likely that poppet valves with separate admission and exhaust passages would prove to be sufficient for single expansion from pressures in the neighborhood of 400 lb. per sq. in., without compounding, if the steam were superheated to 750 deg. fahr. In either case, compounding or higher superheat would simply enable us to maintain a constant efficiency ratio, thus gaining the total 23 per cent due to the higher Rankine efficiency. It was therefore erroneous, in figuring out the advantage resulting from higher pressure, to add the gain from compounding determined by experiments with low pressures to the increased Rankine efficiency of the higher pressure. If a further increase in power were desired, higher pressures had been used. Another increment of gain amounting

[7] General Engineer, Westinghouse Electric & Mfg. Co., So. Philadelphia Works, Philadelphia, Pa. Assoc-Mem. A.S.M.E.

[8] Consulting Engineer, New York, N. Y. Assoc-Mem. A.S.M.E.

[9] Consulting Engineer, American Locomotive Company, Schenectady, N. Y. Mem. A.S.M.E.

[10] R. Garbe, Die Dampflokomotive der Gegenwart. Second edition, 1920, pp. 192–193.

incidentally to 23 per cent could be obtained by a further doubling of pressure from 400 to 800 lb. per sq. in.[11] However, it would be hardly advisable to use large riveted drums for these pressures and high temperatures, and it was questionable whether forged drums could be manufactured sufficiently cheaply to be suitable for locomotive use. In the German high-pressure boiler described in the paper the water-tube firebox was separated from the fire-tube barrel, thus permitting use of the pressure in the former to 800 lb., lowering at the same time that in the latter to 200 lb. per sq. in. The whole locomotive with its two-pressure boiler, double expansion of steam, mixing of low-pressure superheated steam with the exhaust steam from the high-pressure cylinder, resembled a modern high-pressure stationary installation consisting of a high-pressure water-tube boiler, a two-stage expansion engine or turbine, and a Ruths storage heat accumulator between the high- and low-pressure engines.

In this particular instance the construction was still more complicated by using the indirect method of steam generation. It had the advantage, though, of permitting the use of distilled water in the hottest part of the boiler, thus eliminating any scale formation inside water tubes; in addition the lower part of the high-pressure drum was not exposed to the hot gases in the firebox. This arrangement might prove to be of great value for districts with bad untreated water; for railroads with fair or treated water the indirect steam generation would probably represent an unnecessary complication, and it was possible that an ordinary water-tube boiler in combination with a low-pressure tubular boiler might turn out to be just as good a proposition. In the two-pressure boiler only part of the working steam had 800 lb. pressure, the other part being of 200 lb. only. The total gain in ideal efficiency would be, therefore, less than the 46 per cent given in the table, and it would depend upon the ratio of steam generated in the high-pressure boiler to the total amount of steam. However, if this ratio could be kept somewhere between 70 and 80 per cent, the total gain might still amount to 30–35 per cent. We might have in the future two types of boilers—one of the connected water- and fire-tube type for pressures in the neighborhood of 400 lb. per sq. in., and another of the separated water- and fire-tube type for higher pressures, probably about 800 lb. gage pressure. In both cases superheat would be between 700 and 750 deg. fahr. until material to withstand higher temperatures became a market product.

The study which Mr. G. G. Bell, of the West Penn Power Company, had made in 1925 on the question of the most economical pressures for stationary plants had shown that the higher the cost of coal and the higher the load factor, the more advisable was the use of high pressures. For the reheating cycle the most economical pressures were between 340 and 500 lb.; for the regenerative cycle they were higher—between 440 and 600 lb.[12] This would indicate that there is no need for going beyond 500 lb. per sq. in. for locomotives. This was in agreement with the investigations of Prof. A. G. Christie, who favored pressures of only 400–500 lb. per sq. in. with very high superheat.[13] However, the high evaporative rate required from a locomotive boiler might change these findings.

V. L. Jones[14] stated that the conventional type of locomotive had reached its limit of capacity and economy with boiler pressures remaining at 200 lb. per sq. in. Major increases were only possible through radical increases in steam pressure. Improvement of the locomotive could only be effected by keeping in mind the plant as a whole. Up to the present time it had been the general practice to add devices and equipment to a boiler which, basically, did not differ from designs laid down many years ago. We were now forced, however, to attack the problem on the basis of a general redesign of the entire evaporating plant. The feed-heating section, the evaporating section, and the superheating section of the boiler all had to be properly proportioned as a part of a total design, and the system of starting with a standard-type boiler and adding feed-water heating and steam-superheating equipment should be discarded.

[11] This incidentally showed that the increments of Rankine efficiencies varied approximately in arithmetical progression when pressures varied in a geometrical progression, following very closely the parabolic law.

[12] Serial Report of the Prime Movers Committee, National Electric Light Association, on Higher Steam Pressures and Temperatures, July, 1926, pp. 20–21.

[13] Ibid, pp. 4–7.

[14] Assistant Mechanical Engineer, New York, New Haven & Hartford R.R. Co., New Haven, Conn. Jun. A.S.M.E.

It appeared that to date the ultra-high-pressure boiler of the German State Railways represented a more complete development than any other equipment now in service, particularly where the question of water-tube fireboxes and bad water was considered. The German design restricted the fluid in the water-tube sections within a closed system, all amounting to a combination of boiler and condenser. There was further evidence of proper coördination in the German design in the use of moderate-pressure steam in the low-pressure cylinders combined with the high-pressure boiler, with very good results from a heat-balance standpoint. The authors had mentioned that higher pressures carried with them increasing difficulty on account of scaling, washing, and cleaning of locomotive boilers due to the almost universal use of untreated water. In some sections of the country the quality of water for boiler feed was extremely bad, resulting in high maintenance and loss of use of locomotives. With the staybolt type of firebox construction, these troubles increased very definitely with an increase in pressure, but with a water-tube firebox construction there did not appear to be quite as much difficulty in firebox inspection, cleaning, and general maintenance. The experience with the Brotan firebox in Austria and experience in this country with the Muhfeld and McClellon fireboxes justified this statement.

The more general use of water-tube construction should allow greater capacity and greater power output from the boiler plant, with an ultimate reduction in maintenance and loss of use. With the use of higher pressures the locomotive would have to undergo general, coördinated changes so that greater economy and capacity at the tender drawbar without exorbitant increases in weights and costs could be obtained. There would be modifications in running gear, to match up steam-distribution characteristics. Increase in boiler pressure entailed multiple expansion in the cylinders. Compounding introduced difficulties, and the use of more than two cylinders was productive of complications, but unless these difficulties were overcome, the use of steam pressures in excess of 250 lb. would be limited. It was not a simple matter to increase the boiler pressure indefinitely without due provision for proper expansion in the cylinders.

W. F. M. Goss[15] referred to his work of twenty-five years ago. On the basis of the normal locomotive of that day and the results of a series of tests more elaborate than any which had ever before been made upon a steam locomotive, he had reached the conclusion that larger boilers with better evaporative efficiency rather than stronger boilers with higher pressures, were to be preferred. But the progress of a quarter of a century was irresistible, and he was now in favor of higher pressures.

R. Eksergian[16] wrote that the potential heating energy of the coal was equal to the summation of the unavailable energy components plus the increases of unavailable energy resulting from transformations, throttling, imperfect engine-cycle losses, etc., plus the direct losses of available energy as in the exhaust, etc., plus the useful work performed. Since the heat of combustion was transferred to the steam by radiation and by convection, the unavailable energy was decomposed into two components, the unavailable radiant energy and the unavailable energy of the products of combustion. The lower temperature limit fixed the magnitude of the two unavailable energy components. In considering the direct losses we had, first, the losses due to unburnt fuel (dependent upon the rate of firing and some inverse function of the firebox volume); second, the transformation losses from the gases to the steam; third, the losses due to throttling and imperfections of the engine cycle; and finally the available energy losses in the stack gases and the exhaust steam, respectively. A second-law heat balance was therefore:

1. Direct Loss Due to Unburnt Fuel
2. Unavailable Energy
   - *a* Radiant-energy component
   - *b* Products of combustion (i.e., firebox gases)
3. Increases of Unavailable Energy
   - *a* Heat-transfer loss to steam
   - *b* Engine-cycle losses, throttling, etc.

[15] Barnstable, Mass. Past-President A.S.M.E.

[16] Engineer, Baldwin Locomotive Works, Philadelphia, Pa. Mem. A.S.M.E.

4 Available-Energy Losses
  a Available energy of stack gases
  b Available energy of exhaust steam
5 Useful Work
  TOTAL = Heating Value of Fuel.

2 *Unavailable-Energy Components.* The unavailable radiant energy was small because the upper temperature limit was high and remained constant in the process. On the other hand, the products of combustion transferred their heat by a cooling process and the effective temperature head was gradually reduced as the gases passed along the tubes, resulting in a serious increase of unavailable energy. This necessary cooling effect from the firebox temperature to the smokebox temperature resulted in a large percentage of unavailable energy. Thus the process of radiant-energy transformation was far superior to the convection process which resulted in a cooling of products of combustion and low efficiency. Considering the lower temperature limit fixed by atmospheric exhaust, the unavailable energy had to remain fixed.

3 *Increases of Unavailable Energy.* This was caused by heat transfer from a higher to a lower temperature head and in throttling losses, resulting in eddying and reheating at lower temperature. The radiant heat was transferred to the steam from a fixed high temperature to the temperature of the steam. With ordinary steam temperatures the increase of unavailable energy here would be large. In the convection process from the heated gases to the steam, the temperature head of the gases gradually diminished to the smokebox temperature, so that the heat transfer near the firebox end resulted in a large, and that at the smokebox end in a small, increase of unavailable energy. The region where the steam temperature should be increased was at the firebox. By efficient engine cycles, large expansion ratios, etc., throttling losses could be reduced. In a reciprocating engine, by the cooling effect of the cylinder walls, energy was transferred to and from the cylinder walls, with a loss of temperature head and a resultant increase of unavailable energy. This and the throttling losses, due to wire drawing and release, were the principal causes of the cylinder losses or increase of unavailable energy.

4 *Available-Energy Losses.* The major available-energy direct losses were, the available part of the energy of smokebox gases, the available energy in the exhaust steam, and the direct loss due to unburnt fuel. This latter increased very rapidly with high ratios of firing. In addition, we had secondary losses resulting in external radiation, cooling, etc.

5 *Useful Work.* Finally, we transformed ordinarily less than 8 per cent of the available energy of the coal into indicated work in the cylinders. From the available traction we further subtracted the friction losses which amounted to over 15 per cent of the i.hp. The various components might be tabulated as follows:

	B.t.u. per lb. coal	Per cent
Direct Loss Due to Unburnt Fuel	2800	20.00
Unavailable-Energy Components		
a Radiant-energy component	556	3.97
b Firebox gas component	2930	20.90
Increase of Unavailable Energy		
a Heat transmission	4274	30.50
b Engine cycle throttling	684	4.89
Available-Energy Losses		
a In the stack gases	340	2.43
b In the exhaust steam	1207	8.62
Useful Work (thermal)	1209	8.64
	14,000	100.00

We had no control over the unavailable-energy components or the available-energy losses. They were due to the external temperature limits and the medium which we utilized for conversion of heat into mechanical work, the products of combustion and steam. Therefore the fruitful field was in reducing the heat-transmission losses and engine-cycle losses. Improving engine-cycle efficiencies was only about 14 per cent as effective as reducing the heat-transmission loss. This meant raising the temperature of the steam, and particularly at the firebox where the greatest heat-transmission loss occurred.

The method of estimating these various components was illustrated in the following calculations.

Effective Radiant Emissive Surface.

Let n = pounds of products of combustion per lb. of coal
A_g = area of grate, sq. ft.
A_e = equivalent emissive surface, sq. ft.
t = flame temperature in firebox, deg. fahr.
R = rate of firing, lb. per sq. ft. per hr.
C = constant depending upon ratio of grate to firebox surface, volume, etc.

Assuming a temperature of feedwater of 70 deg. fahr., 12.0 lb. of products of combustion per lb. of coal actually fired, a combustion efficiency of 75 per cent, and a mean firebox temperature of 2490 deg. fahr., the ratio of A_e to A_g would be 2.31.

$$nR\int_{70}^{t}(a + bT)dT + \frac{A_e}{A_g} \times 1600\left[\left(\frac{460 + t}{1000}\right)^4 - \left(\frac{460 + t_s}{1000}\right)^4\right] = 14{,}000\ (1 - CR)R$$

Substituting the above values, t = 2490, t_s = 382, $(1 - CR)$ = 0.80, and R = 90, while a = 0.24 and b = 0.00002, it would be found that A_e/A_g = 2.32.

Radiant-Energy Components. Total heat transferred by radiation per lb. of coal fired =

$$\frac{A_e}{A_g} \times 1600\left[\left(\frac{T}{1000}\right)^4 - \left(\frac{T_s}{1000}\right)^4\right]\frac{1}{R} = 3100 \text{ B.t.u. per lb. of coal;}$$

of this the unavailable component was

$$3100 \times \frac{T_0}{T} = 3100 \times \frac{530}{2950} = 556 \text{ B.t.u.}$$

where T_0 = 490 + 70, and T = 2490 + 460, while the available component was

$$3100 - 556 = 2544 \text{ B.t.u. per lb. of coal}$$

Energy Components of Firebox Gases. The total heat from combustion per lb. of coal was 14,000 × 0.8 = 11,200 B.t.u. per lb. of coal. Therefore the total energy of firebox gases was 11,200 — 3100 = 8100 B.t.u. Of this the unavailable component was

$$nT_0\int\frac{dQ}{T} = nT_0\int_{530}^{2950}\frac{(a + bT)dT}{T}$$

$$= 0.24 \times 12 \log_e \frac{2950}{530} + 0.00048\ (2950 - 530) = 2930 \text{ B.t.u.}$$

and therefore the available component was 8100 — 2930 = 5170 B.t.u.

Energy Available for Heat Transmission and Energy in Smokebox Gases. This obviously consisted of the available components of the radiant energy and the firebox gases, minus the available energy in the exhaust gases. The total heat of the smokebox gases at 490 deg. fahr. was

$$nT_0\int_{530}^{950}\frac{(a + bT)dT}{T} = 1284 \text{ B.t.u per lb. of coal,}$$

while the unavailable component of this heat was

$$nT_0\int_{530}^{950}\frac{(a + bT)dT}{T} = 944 \text{ B.t.u. per lb. of coal,}$$

and the available component

$$1284 - 944 = 340 \text{ B.t.u. per lb. of coal.}$$

Therefore the energy available for heat transmission was

$$2544 + 5170 - 340 = 7374 \text{ B.t.u. per lb. of coal.}$$

Energy Components of the Steam. The total heat of the steam was divided into its available and unavailable portions. Again, the exhaust steam might be likewise subdivided. The difference between these available components is the change in availability due to performance of work in the cylinders. It would always be found

(Continued on page 897)

Measurement of Static Pressure

By CARL J. FECHHEIMER,[1] EAST PITTSBURGH, PA.

The paper describes a new instrument for measuring static pressures in air-flow determinations. Made in the form of concentric brass tubes, the outer of which is $^1/_4$ in. in diameter, the instrument is easily introduced into air ducts through small openings, such as a bolt hole. Pressure is communicated to manometers through two holes, one to the inner tube and the other to the concentric space between the tubes, about 78.5 deg. apart. The instrument is held perpendicular to the flow in such a manner that the direction of flow bisects the angle between the axes of the holes. In this position, which can be determined by balancing the pressures on one manometer, the reading on a second manometer gives the static pressure. The instrument has less error in turbulent flow than other types.

THE usual way of measuring static pressure in a stream which flows at a comparatively high velocity, is by means of a static plate, piezometer ring, or the static side of a pitot tube. In all three the direction of stream flow is parallel to the axis of the walls or of the tube. If the character of the flow is turbulent, but is made up of regular defined systems of whirls, the flow adjacent to the walls is laminar, as has been proved experimentally.[2] With laminar flow there are thin layers adjacent to the boundaries that are stationary, and consequently, if connected through a small hole to a manometer, that instrument reads the static pressure. There are cases, however, in which the changing character of the inner wall surface causes the moving fluid to impinge thereon; again, it is not always convenient to arrange for using such a device and to provide for connection to a manometer. It usually is satisfactory, however, to provide for a hole large enough to pass a small metal tube through, a bolt often being removed temporarily. Especially if it is to be used for measurement of the static air pressure in the end bell of an electrical machine, such as a turbo- or salient-pole alternator, is this a convenient method. But then an ordinary tube is not satisfactory, as the reading on the manometer is due partly to static pressure and partly to velocity head. Thus a considerable error may be introduced, because a fraction of the velocity head may be added to or subtracted from the static pressure.

It was thought at an earlier time that a tube with very small holes, uniformly distributed all around, should read substantially correct, as for some holes the velocity head adds to, and for others it subtracts from, the static pressure, the net result being negligible influence of velocity head. It was recognized, however, several years ago that such a device was not satisfactory, and from some recent calculations it appears that the reading is low by about 50 per cent of the velocity head.

The author developed a device for measuring static pressure as described in the July, 1923, issue of the *Electric Journal*, and the next year in a paper on Performance of Centrifugal Fans for Electrical Machinery.[3] That device is too cumbersome to use generally, and its readings may be affected by jets and the like. The device herein described was suggested by the curves in a paper of the Bureau of Standards.[4] It is believed that it can be used easily, and can be passed through a bolt hole and held in the stream. While there may be a small error due to the influence of velocity head, that error is considerably smaller than with any other device known to the author.

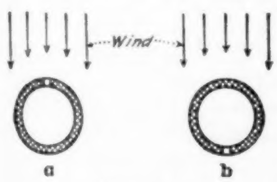


Fig. 1

It is evident that if on a hole in a circular tube a fluid be allowed to impinge as in Fig. 1*a*, the reading on a manometer connected with the tube is nearly the static plus the velocity head. If the tube is turned through 180 deg. (Fig. 1*b*), the reading is somewhat more than the static minus the velocity head. It is evident that, somewhere between those two positions, there is some position for which the influence of velocity head is zero. If the tube can be turned through such an angle, the static pressure will be read. In the course of his work at the Bureau of Standards, referred to above, Dr. Dryden took observations of the sum of velocity and static heads on cylinders of various diameters, the cylinders being rotated about their axes, and a small hole was drilled in the wall of each through which the fluid entered. These tests showed that the angle between the direction of stream and the position where the influence of the velocity head was zero was a little less than 40 deg. For smaller angles the influence of the velocity head was positive, and for larger angles it was negative. If the exact value of this angle (which we shall call the critical angle) were known, and if a tube with a small hole were placed in a stream with the hole at that angle to the stream, the reading on the manometer should be the static only.

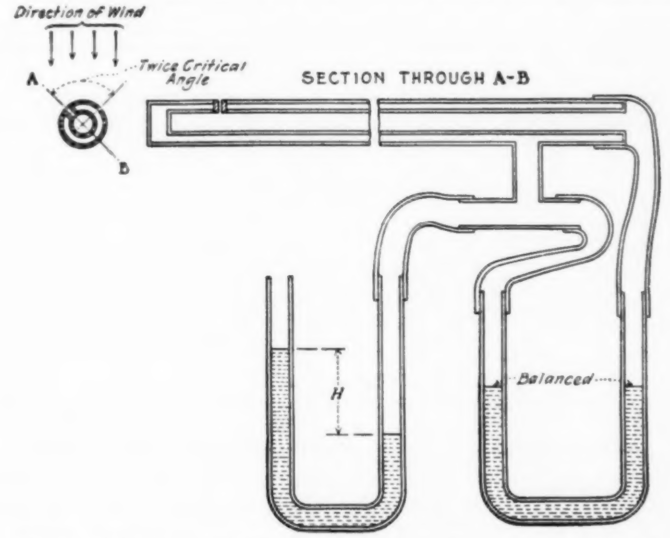


Fig. 2 Manometer Connections for Measuring Static Pressure

The device as built consists of two small brass tubes (as shown in principle in Fig. 2), the diameter of the outer one being $^1/_4$ in., and of the inner, $^1/_8$ in. The inner tube communicates with the outer surface through a small hole, and the annular space between the two tubes communicates with the outer surface by means of another small hole displaced from the first hole circumferentially by double the critical angle. The inner and outer tubes are then connected independently to the two sides of a U-shaped tube or other manometer, and when the device is in a moving stream, it is turned on its axis until the U-tube reads zero. Then the stream bisects the double angle, so that if one side of the U-tube is then opened to the atmosphere, the static pressure only will be read. There is, of course, the possibility that the tube be turned 180 deg. from the impact side, and then the reading would be too low. To overcome this difficulty, it has been found advisable to use two manometers, one for balancing and one for reading the static pressure, a suitable T-connection being used on one side for connecting to the second manometer. Then the manometer used for balancing would read zero for the two positions of the pressure tube, which are 180 deg. apart. The second manometer, which reads the pressure, would then record a high and a low value for the two balanced positions. The high value is the correct static pressure.[5]

[1] Research Engineer, Power Engineering Department, Westinghouse Electric & Manufacturing Co.

[2] On the Boundary Conditions of a Fluid in Turbulent Motion, by T. E. Stanton, Miss Marshall, and Mrs. Bryant. Proceedings of the Royal Society, August 3, 1920.

[3] Trans. A.S.M.E., vol. 46 (1924), p. 287.

[4] Air Forces on Circular Cylinders, Hugh L. Dryden. Scientific Paper No. 394.

Presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers.

[5] If the pressures are below atmosphere, the higher reading is the one that is numerically smaller.

The tube as it was constructed is shown in Fig. 3. The small projection shown at the line A-A was silver-soldered into the small tube, and a hole was drilled into the outer tube of the size of the diameter of the projection. The small tube was then pushed into the large one, and after the projection was passed through the hole in the outer tube, the projection was soft-soldered in place. The two holes of about 0.02 in. diameter were drilled $78^1/_2$ deg. apart. Careful tests were made to insure that there was no leakage

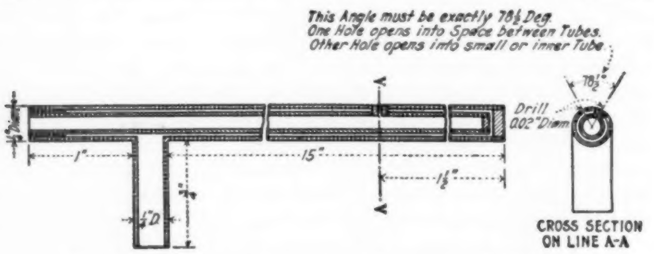


Fig. 3 Brass Static-Pressure Measuring Instrument

(Large tube $^1/_4$ in. outside diameter. Must be smooth and true on the outside. Small tube 0.125 in. outside diameter, 0.063 in. inside diameter. All joints must be airtight.)

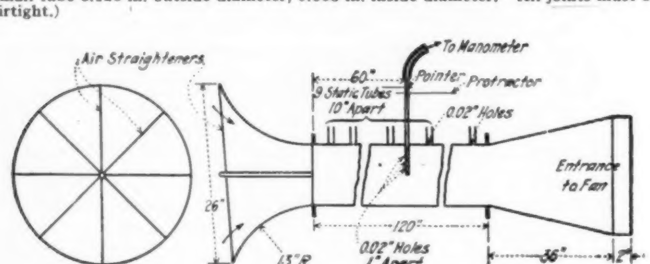


Fig. 4 Experimental Air Duct

(All but one hole was sealed in the small tube for a particular set of observations.)

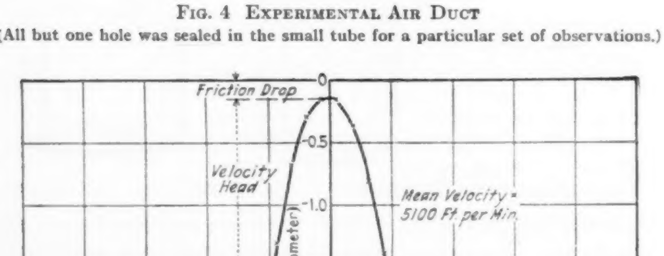


Fig. 5 Pressure Against $^3/_{16}$-In. Cylinder Perpendicular to Air Stream in 8-In. Duct

between the inner and outer chambers after the tube was completed. It was also found later that scratches and slight departures from a true cylindrical surface on the outside affected the results. The tube was consequently ground, so as to make it a substantially perfect cylinder.

The tests made at the Bureau of Standards could not be used directly to determine the exact value of the angle between the two holes. These tests were made on cylinders much larger than those which we could use, and realizing that the angular position of the holes was of vital importance, tests were made to determine it. For this a long duct was constructed 8 in. in diameter with a bell-mouth entrance, and with air straighteners therein, as shown in Fig. 4. Small static-pressure tubes were distributed throughout the length of this duct, and, with the excellent entrance conditions producing a smooth flow, the static pressures were measured quite accurately along the duct. The air was drawn directly from the atmosphere into this duct. About half-way down the duct a small brass tube with holes of 0.02 in. diameter, arranged 1 in. apart, was inserted. A pointer was attached to this tube, which, in conjunction with a stationary protractor, enabled the observer to determine the angular position. The tube was connected with a suitable manometer, and readings were taken for various angular positions. This was repeated for a tube of slightly different diameter, and for one with a spherical cup at the end instead of a square end. It was found that the location of the hole axially, or the use of a spherical instead of a square end, had practically no influence upon the critical angle. A few of the results of these observations are plotted in Figs. 5, 6, and 7. It is believed that these curves require no further explanation. Tests were also made in a duct $1^1/_{16}$ in. in diameter, but the results showed that the tube disturbed the flow so much that the static pressures ahead and behind the cylinder were considerably different. The device is not recommended for the measurement of static pressures in small ducts.

Tests were also made with the air issuing from an orifice into the atmosphere, in which case the static pressure was that of the

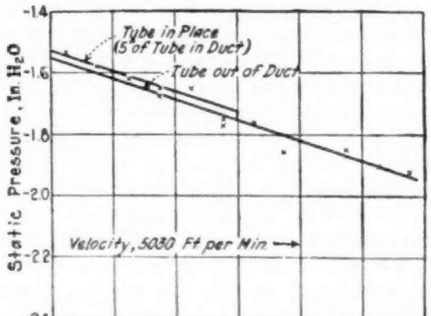


Fig. 6 Static Pressure Along 8-In. Duct, $^3/_{16}$-In. Cylinder Projecting 5 In. into Duct

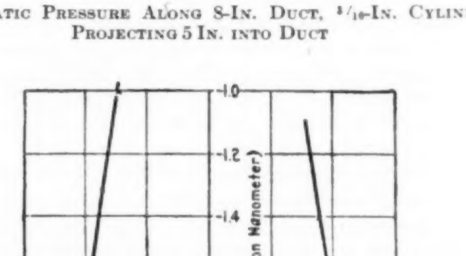


Fig. 7 Pressure Measured at 0.02-In-Diameter Hole 1 In. from End of a $^3/_{16}$-In-Diameter Cylinder and at the Center of an 8-In-Diameter Duct

(Mean velocity, 5020 ft. per min. Cylinder axis perpendicular to direction of the stream.)

atmosphere, which is usually taken as zero for reference. The results of this test are shown in Fig. 8. The two curves were taken with the axis of the tube normal to the air stream and at 45 deg. to the air stream. It will be seen that the angular position differs slightly for the two angles of inclination of the tube. When the device is used for measuring pressure in end bells of electrical machines, the direction of flow is not known. That is why it is important to recognize that slight errors may be introduced in the reading.

The tube as constructed, in which the holes are $78^1/_2$ deg. apart, was used to determine the magnitude of the error for different

angles of inclination with the air stream. These may be tabulated as follows:

Angle, deg.	Error, as per cent of velocity head
90	10 per cent high
80	$6^1/_4$ per cent high
45	3 per cent low
30	$1^1/_2$ per cent low

The errors as reported are usually quite small. For instance, if in the end bell of a turbo-alternator the static pressure is 10 in. of water and the velocity of the air adjacent to the tube is 5000 ft. per min., the error, if the tube is normal to the stream, is $0.1\ (5000/4030)^2 = 0.154$ in. water. This is only 1.54 per cent of the static pressure, which is a comparatively small error. As previously stated, with the tube that has been used before, the error

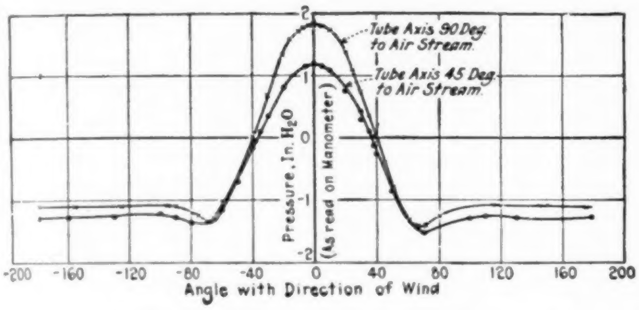


Fig. 8 Pressure Distribution Around a $^1/_4$-In. Cylinder in the Atmosphere

(Static pressure is zero for reference. Velocity, 5400 ft. per min.)

was substantially 50 per cent of the velocity head. With most measurements the error is less than indicated by these figures, for generally the tube is inclined with the air stream, in which case the percentage of error decreases.

When the stream is highly turbulent, it is difficult to state the static pressure. There are probable interchanges from static to velocity head, and vice versa, and it is therefore impossible to define the static pressure; consequently an accurate measurement cannot be made. In such cases the best that can be done is to standardize upon some method of measurement, which would serve as a basis for comparison between similar ducts, chambers, etc. It is believed that measurements with the tubes, as described herein, might serve for such basis, or at least until the character of turbulent flow is understood better than it is at present.

By attaching a pointer or other suitable device the tube may be used as a direction finder, and as such is sensitive and very accurate.

Mr. G. W. Penney conducted tests at the Laboratories, and the value of his work is hereby acknowledged.

Discussion

H. L. Dryden[6] submitted a written discussion in which he said that the author had adapted a device, used by wind-tunnel experimenters for many years as a direction finder, to the measurement of static pressure in turbulent air streams. The errors of the instrument would probably never exceed 10 per cent of the velocity pressure, and in most cases would be much less.

The angle between the two positions on the cylinder at which the pressure equaled the static pressure varied with the size of the cylinder, with the distance from the end of the cylinder, and with the wind speed. The maximum included angle ever observed was 84 deg., although, theoretically, for extremely small cylinders at low wind speeds the angle could approximate 90 deg. This value of 84 deg. was nearly reached in Figs. 5 and 7 on a $^3/_{16}$-in. cylinder, 1 in. from the end. This value had also been found at Langley Field, Va., for the center of a 1-in. cylinder extending completely across the air stream. The lowest values obtained for cylinders not exceeding 1 in. in diameter were about 74 deg., although measurements on 1-in. cylinders inclined as in Fig. 8 were not available. Now the error in static pressure produced by an error of 5 deg. in the location of the holes was about 8 per cent of the velocity pressure, so that a tube with an angle between the holes of 80 deg. should not give an error greater than 8 per cent of the velocity pressure. For particular purposes a judicious selection of the angle would reduce the error. For example, if the stream were known to be nearly perpendicular to the cylinder, the use of holes 0.02 in. in diameter, 1 in. from the end of a $^3/_{16}$-in. cylinder, with an angle between the holes of 82 deg. would make the errors less than 5 per cent.

Care had to be taken to keep the instrument small compared to the cross-section of the duct. Fig. 6 showed that even in an 8-in. duct the flow was perceptibly affected by the introduction of a $^3/_{16}$-in. tube. With these considerations in mind, results of a very satisfactory degree of accuracy could be obtained.

E. N. Fales[7] wrote that since care was specified in the construction and use of the instrument described by the author, there was a further use to which it might be put, namely, the measurement of velocity pressure. Mr. Fales suggested that an impact pressure orifice be located half way between the $78^1/_2$-deg. holes, and offset axially if necessary to avoid interference. A passageway from the impact orifice to a third hose connection would enable the recording of impact, and, therefore, velocity pressures simultaneously with static pressures. The instrument thus modified would then be capable of measuring static pressure, velocity pressure, and direction. Precedent for such impact orifices as the above existed in a half-inch "integrating impact tube" developed for determining at one reading the average impact pressure along the diameter of the McCook Field 5-ft.-diameter wind tunnel. Impacts read on such a tube were reliable if the instrument was carefully handled, and oriented within 1 deg.

An instrument very similar to that of the author had been used in Germany by Dr. Karman and by Dr. Klemperer for precise determination of the flow direction. The angular separation of the two holes was above 66 deg., chosen because the point of inflection of the angle-pressure curve occurred at 33 deg.

Regarding the axial position of holes mentioned by the author, it was assumed that all the positions tested were reasonably far from the end of the tube. Figs. 9 and 10 showed visually how the air flow changed near the end of a cylinder; the pressure changes would probably extend to a further distance from the end than the flow-line distortion in the photographs indicated.

J. M. Spitzglass[8] wrote that the idea prevailed that an opening facing the flow obtained the full velocity head plus the static pressure at the point of measurement. The difficulty had always been considered to be the determination of the true static pressure, which, subtracted from the total, would give the correct velocity head at the given points. The author had found a method for determining the true static pressure. But how was the true velocity pressure to be determined, in view of the inference from the fourth paragraph of the paper, that the total pressure on an opening facing the flow was not exactly the static pressure plus the velocity head?

It might be inferred, however, that this statement did not apply to impact tubes, where the opening was sharp-edged against the flow. If such was the case, a third opening would have to be provided in a separate tube to obtain the true impact or total pressures. Could the author advise how the third tube was to be arranged so that its registration could be considered complementary to the registration of the static pressure, and at the same time not cause any disturbance by the proximity to the other tubes?

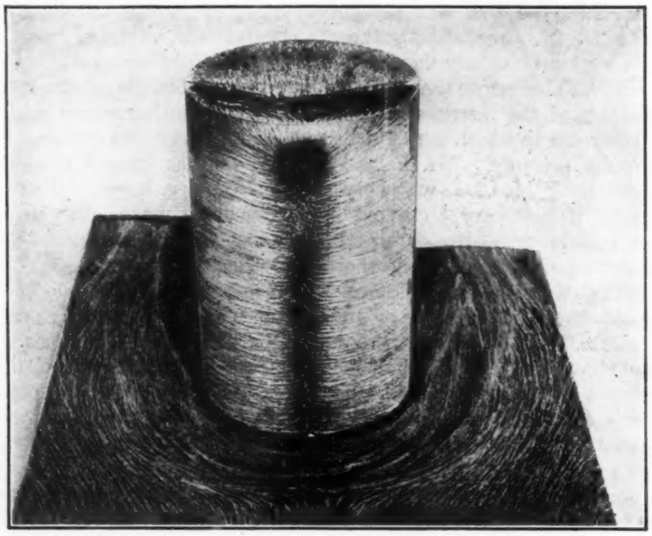
It was interesting to note in Fig. 5, where the static pressure was shown against a $^3/_{16}$-in. cylinder, that the lowest pressure corresponded to twice the critical angle, and that the effect of suction at that angle was practically the same as the effect of impact when the opening was facing the flow. This being the case, a combined tube could be built so as to have the high- and low-pressure openings placed at the respective angles to produce the maximum differential. This would materially increase the accuracy of the readings and would eliminate the necessity of determining the exact static pressure. That was, the tube would register, directly, twice the velocity head of the given flow.

[6] U. S. Bureau of Standards, Washington, D. C.

[7] Aeronautical Engineer, U. S. Air Corps, McCook Field, Dayton, Ohio.

[8] Vice-President, Republic Flow Meters Co., Chicago, Ill. Mem. A.S.M.E.

Frank W. Caldwell[9] wrote that it was known that the flow of air around a cylinder might change for a different velocity or turbulence of the flow, or for different sizes of the model. Tests at McCook Field had shown this for spheres, airfoils, and struts; and tests at the Bureau of Standards had shown it for cylinders. Lacking information to the contrary, it would not be wise to assume that the point of zero static pressure always occurred at $39^{1}/_{4}$ deg. It was thought that for uses differing greatly from the specific cases discussed by the author, calibration of the instrument in a wind tunnel would be a good precautionary measure.



FIGS. 9 AND 10 AIR FLOW AROUND CYLINDER, LOOKING, RESPECTIVELY, DOWN WIND AND ACROSS WIND
(4-in. cylinder, 6 in. long; air speed, 30 m.p.h.)

Regarding Fig. 6, similar conditions in the McCook Field 5-ft.-diameter wind tunnel gave different results. If a $^{1}/_{2}$-in.-diameter tube was inserted diametrically through the tunnel, the longitudinal pressure gradient upstream of the tube remained the same as when the tube was removed. But downstream of the tube the negative pressure was greater when the tube was in the tunnel than when out. Thus the curves for the two cases lay together upstream of the tube, and apart downstream. This was the reverse of the condition of Fig. 6.

Sanford A. Moss[10] wrote that the statements and experiments of the author seem sound. Dr. Moss had made an instrument to the author's specifications and tested it in a jet discharged from a flow-measuring nozzle into the atmosphere, checking all the data in the paper. As the author pointed out, at various angles and positions the tube did not give exact static pressure, but a fairly close approximation to it. Emphasis should be laid on the fact that any device which measured the force on a portion of a wall was subject to exactly the same errors due to the impact of stray jets as is an ordinary static hole in the same place.

G. W. Penney[11] wrote that the static-pressure measuring tube under consideration had proved to be very valuable for measuring pressures in end bells and other similar places where the flow was very turbulent, so that ordinary methods were useless, and even in straight ducts it was more convenient than arranging special-pressure measuring holes, because it could be inserted in a bolt hole. It had been found that the instrument was very sensitive to small particles that might lodge in the holes where they would not be wiped off with a rag. Any slight scratch in the surface of the tube near the pressure-measuring holes would also disturb the flow and make the readings inaccurate. For this reason, the tube was usually checked before using by holding the tube at some point where an air stream was discharging from a duct into the atmosphere. If the tube was held a short distance from the point where the air left the duct, the static pressure would be atmospheric, but there would be considerable velocity head. If the tube read atmospheric under these conditions, it was functioning correctly.

The author, in his closure, said that it was gratifying to note that the discussers were in agreement regarding the practicability of the device described in the paper. There seems to be a belief that the double angle of 78.5 deg. might not be as accurate as it should be. Mr. Penney had conducted a large number of tests, and an analysis of them had seemed to indicate that the angle chosen was the correct one. It would be very valuable to us to secure more tests, in a wind tunnel, as suggested by Mr. Caldwell; and go further so as to cover cylinders of various diameters, at various air velocities, at different distances from the end of the tube, as implied by Dr. Dryden. If such further tests were made, they should also include some with the axis of the tube at various angles with the direction of the flow of the fluid, and should be made in ducts of various diameters. At the time the author's tests had been made, it was felt that the cases had been covered sufficiently for determining the value of the critical angle. The recommended value of 78.5 deg. was somewhat of a compromise, taking into account the various angles that might obtain between the tube axis and the direction of the stream; see Fig. 8. It was interesting to note that Dr. Moss had made a similar instrument and checked the author's results.

The point raised by Mr. Fales, and discussed further by Mr. Spitzglass, regarding the use of an impact orifice, was of interest. One difficulty would lie in the uncertainty of the direction of flow of the fluid. It was evident from Fig. 8 that with the tube axis inclined at 45 deg. with the stream, the velocity pressure was considerably less than it was at 90 deg., as one would expect. It was the opinion of the author that if the tube axis was normal to the stream, a small impact hole should give a means of measuring the velocity plus the static pressures. To answer Mr. Spitzglass, it was believed that a tube as suggested by Mr. Fales could be used satisfactorily, three manometers being employed. It would then be necessary, first, to rotate the tube on its axis until the balancing manometer for the static pressure read zero; and, second, to change the direction of the tube axis with the direction of the stream until a maximum reading was obtained on the impact manometer, checking back again on the balancing manometer to see that it read zero. The author had not tried this out, but perhaps others who had use for such an instrument might wish to do so.

It was believed that there should be further checking before use was made of the suggestion of Mr. Spitzglass that accuracy of the reading be increased by employing the lower cusps of the curve of pressure, which seemed to occur at double the critical angle. The author believed that uncertainties were liable to be introduced which would more than offset the increased accuracy due to doubling the reading.

[9] Chief, Propeller Branch, Air Corps, War Dept., McCook Field, Dayton, Ohio.

[10] Engineer, Thomson Research Laboratory, River Works, General Electric Co., West Lynn, Mass. Mem. A.S.M.E.

[11] Power Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Low-Temperature Distillation

A General Discussion Dealing with Three Typical Processes of Low-Temperature Distillation, the Calorific Value of the Semi-Coke Produced, and the Price at Which the Coke Should Sell, and Including a Conservative Estimate of Production Costs and Profit

By W. RUNGE,[1] NEW YORK, N. Y.

THE purpose of this paper is to give a general idea of low-temperature distillation, correcting, if possible, some of the erroneous statements that have been made regarding it, and at the same time showing some of its potentialities and advantages.

Briefly, the purpose of low-temperature distillation is to remove from bituminous coal those ingredients which are smoke-producing, and which upon being removed as by-products have a greater value as such than as fuel, and at the same time produce a smokeless, solid residue which is well suited for either domestic or industrial heating purposes.

Many claims have been made by investigators and promoters of the vast amount of revenue that it is possible to obtain by distilling coal at low temperatures. It is true that a substantial and desirable profit is not only possible but also probable, but we must not let our fancy run wild with the expectation that each ton of coal treated by low-temperature distillation is going to yield at least \$10 to \$15 profit per ton of coal distilled. It is only recently that the author noticed an article in a daily newspaper wherein it was stated that the revenue from the carbonization of a ton of straw was \$250. This on the face of it is ridiculous, but only slightly more so than some of the claims made for low-temperature carbonization.

Many promoters in dealing with this subject go into the possible uses of a large number of so-called derivatives, citing, for example, the possibility of using the products from low-temperature tar in the preparation of dyestuffs, pharmaceutical preparations, and many other chemicals, and set up opposite each an enormous value. As a matter of fact, very little work has been done in these special fields with the compounds found in low-temperature tar, for they form an entirely different chemical group, and few of the derivatives can be used for dyestuffs or pharmaceuticals. We must therefore limit ourselves in thinking of low-temperature carbonization to an average profit of one dollar to four dollars per ton, and in exceptional cases to a profit which may be somewhat higher.

Low-temperature distillation has been given serious thought for quite a long time, and has for the past 15 or 20 years been subjected to very serious and intensive investigation. The processes that have been investigated and described are too numerous to mention, but the author does not doubt that at the present time there are at least 30 or 40, if not more, that are being studied here in the United States and abroad. No attempt will be made here to describe these processes minutely, nor except in a brief way will the theory upon which some of them are founded be discussed. Further, reference to the names these various processes bear will be omitted.

Distillation in the Rotary Kiln

Probably one of the most common types of furnace that is used in low-temperature distillation is known as the rotary kiln. This type has been before the public for quite a number of years. Usually it very closely resembles the cement kiln in its general features and is about 8 to 10 ft. in diameter, 80 or 90 ft. long, and slightly inclined off the horizontal. It is externally heated and its shell is usually of steel, about one-half to three-quarters of an inch thick. It is customary to feed the coal into the upper end of the retort and, due to the rotary motion and the inclination of the retort, discharge it at the lower end. This type has not been particularly successful, for the reason that the temperatures that are required for the distillation of coal, while not high as we usually understand high temperatures, are sufficient, nevertheless, to greatly weaken the strength of the steel shell.

Inasmuch as the coal must be heated to a minimum of 900 deg. fahr., it is quite probable that the steel shell reaches a temperature of 1200 deg. fahr., and in some spots, due to local overheating, probably as high as 1500 deg. At 1200 deg. fahr. or 655 deg. cent., the tensile strength of mild steel is only 25 per cent of that at 70 deg. fahr.; in other words, at the temperatures required for the distillation the strength of the steel has almost reached its minimum.

Inasmuch as the shell not only contains the coal but must also carry the burden of its own weight, it is subjected to severe strains and stresses, and as a consequence the life of these retorts has not been great. In their operation they are limited to the type of coal that may be treated, for strongly coking coal during heat treatment becomes plastic and not only adheres to the shell of the retort but also shows a tendency to cohere, whereby the various lumps of coal in semi-plastic state, as they come in contact with one another, form larger lumps. The larger lumps often contain raw coal which, because of its protective coating of coke, is only distilled with great difficulty. Further, if these lumps become too large the discharge valves cease to function and complete stoppage occurs. We therefore find the cement type of oven more or less limited to coals which have practically no coking properties. The further disadvantage is that in treating a coal of this type the semi-coke is of a soft, porous nature, very light in weight, and is of little use unless put into briquet form. Some investigators have improved upon this type of furnace by using two or three rotary furnaces in series. In this case the coal is first subjected to a moderate heat treatment: that is, a treatment in which none of the volatile products of coal will be distilled, but one which will nevertheless, especially in the presence of air, partially destroy the coking properties of the coal, and thereby prevent its adherence to the shell. The product, after this moderate heat treatment, is then subjected in a second rotary kiln to a higher temperature, with the result that a solid fuel is delivered in the form of hard, dense lumps, varying in size from $^1/_2$ in. in diameter to as large as 10 and 12 in. This process, however, has one of the drawbacks mentioned above, in that the shell of the retort not only carries its own weight but also the weight of the coal that it contains, and it is only a question of time until distortion must take place.

Distillation in the Concentric-Drum Type of Retort

An improvement over this type is one employed in a German process wherein the retort consists of an inner and an outer drum. This retort is also externally heated, but it has the decided advantage that the entire weight of both drums and their contents is carried by the inner drum, which in this case is the colder one. This drum is maintained at a temperature between 400 and 500 deg. fahr., or the point where steel has its greatest strength. The coal is fed into the inner drum and travels on a slight upgrade, being forced upward by vanes therein which act as a screw conveyor. Having reached the top of its flight the coal discharges into the outer drum, and then because of the rotary motion and the declination of the drum, flows toward the feed end, where it discharges. In the inner drum the only heat which reaches the coal is that which passes through the heated coal in the outer drum, and as a result the inner-drum coal is given a moderate heat treatment, which tends to destroy some of its coking properties, so that when followed by the higher heat treatment in the outer drum the coal is not only distilled but is formed into the hard, dense lumps already mentioned.

[1] International Combustion Engineering Corporation.

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Then there is the stationary vertical type of retort arranged in batteries which has become so prominent in England. These retorts in their general operation resemble a high-temperature by-product coke plant, in that they are heated externally and are intermittently charged and discharged. They are of exceedingly low capacity, and great difficulty has been experienced in the past in discharging the retorts due principally to the swelling nature of the coal. The fuel produced by this process is not particularly desirable, in that its density is low and it is extremely friable.

Distillation in the Horizontal Stationary Type of Retort

Another type of retort is one brought out here in the United States, and concerning which quite a little is heard. This retort is a horizontal stationary one, in which the coal is propelled through the retort by means of paddles. It is the author's understanding that new developments have been made on this retort which have brought it to a very high state of efficiency, but the product that it yields cannot be used as fuel. It is very light and fluffy, and must either be briquetted or pulverized. The pulverization would be a rather expensive operation because the abrasive properties of the coke are such that would make the repair item on the pulverizing mills extremely high. There is no doubt that the fuel from this process lends itself very readily to briquetting, but in order to produce a smokeless fuel, which, when all is said and done, is one of the prime objects of low-temperature distillation, it is necessary to bake the briquets in order to remove the smoke-producing ingredients of the binder, and this naturally adds to the cost of the operation. From each ton of coal there is obtained 0.7 ton of briquetted smokeless fuel. Briquetting charges, including the cost of binder, will run in the neighborhood of $3 to $3.50 per ton. To offset this additional cost there must be a difference of $4.50 to $5 between the price paid for the raw coal and the price received for the finished product. It is therefore advantageous to resort to those processes which produce a smokeless fuel in a natural lumpy state and which do not employ briquetting. The price received will be the same as that for the briquetted product, while there will be no additional charge after the product has left the distillation ovens.

Another method is the carbonization of bituminous coal in dust form, which will be considered later.

The author would not have it understood that none of these processes have made progress, nor that they will not succeed. Many of them have been worked out with a sound engineering knowledge of the problems involved, and in some cases investigators have developed the process which they are operating from a crude, experimental one into one that is highly efficient, well operated, and automatically controlled. It appears that one or two have reached the point, or are close to it, where the cost of operation is so far reduced that the value of the products is sufficient to cover all costs. In many other cases, however, the balance sheet is upset by the high cost of maintenance and the low throughput, the latter usually due to a poor heat transfer. There would seem to be no reason, however, why these problems should present any insurmountable obstacle, and the author is confident that several of them at least will soon reach the goal at which they are aiming, and it will then become a question as to which is the most productive and most adaptable to the then existing conditions. He doubts very much whether any one process will be able to fulfil all requirements of both domestic and industrial fuel, and it is more than possible that there will be several, each having advantages over the others in certain special fields.

Those processes producing a solid, lumpy fuel are almost entirely confined to the domestic trade, or to the few industries which use coke for other than blast-furnace or foundry purposes, while those that produce a finely divided, porous form of semi-coke are limited to industrial plants using pulverized fuel.

The question as to whether low-temperature carbonization will pay is one that is often subject to debate, as many factors enter into consideration.

It is impossible to discuss the revenue from a low-temperature distillation plant until the amount of by-products obtainable is determined, and this in turn depends upon the type of coal undergoing treatment. Another important factor is, of course, the cost of raw material. The cost of the raw material includes naturally the price at the mines and the cost of transportation, so in this case we must first endeavor to select the site at which the plant is to be located. This subject was discussed informally at the recent International Fuel Conference at Pittsburgh and there was no consensus of opinion as to the proper location. There are certain advantages in locating the carbonizing unit at the mines. This eliminates a certain amount of freight, and also assures the constant supply of raw material. On the other hand, it is questionable whether the profits would be as great unless there was a market for the gas produced, and such a market is not usually found at the mines. In most cases location at the mines would also have the disadvantage of transporting the liquid by-products great distances. Personally the author feels that the best location is at a point where all of the products of the distillation may be readily disposed of. While some of these fuels will stand transportation very well, nevertheless it would be advantageous to take them from the carbonization plant and deliver them directly to the customer. Should, however, the distribution of gas under high pressures for great distances be realized, then further consideration of plant location would be necessary.

Heating Value of Low-Temperature Coke

While on the subject of fuels, the author would correct an erroneous opinion that many have regarding the heating value of low-temperature coke. He has both read and heard it repeatedly stated that a low-temperature coke has a higher calorific value than the coal from which it is made. His experience gathered from treating coals from many parts of the United States and many different countries has been that the number of B.t.u. per pound of coke will average 700 to 1000 less than that of the coal from which it is made. This is a general rule for high-volatile, low-oxygen coals. In dealing with high-oxygen coals it is quite often found that the heating values of the coal and the coke are about the same, or possibly that of the coke is slightly higher. This is particularly true with lignite, for in most cases there is an upgrading of the solid fuel, and it is not rare to find a lignite whose calorific value is 2000 B.t.u. less than that of the char produced from it.

It is evident from what has been said earlier regarding the marketing of the solid fuel that such a plant should be located in close proximity to a large city. The fuel market is not only larger than in smaller communities, but in all large cities there is also a demand for gas, a demand which does not exist at the mine and rarely exists in the smaller towns. The records of the gas industry show that the demand for gas is doubling every 10 years, so that any gas that is produced by a low-temperature plant should undoubtedly be readily absorbed. We usually find in or about the larger cities tar-refining plants, which should reduce the freight on this liquid product and permit it to be sold at a higher price.

One other product made by low-temperature carbonization is that which is commonly termed "motor spirits," and as this product can be produced at the distillation plant in the pure form, its demand will naturally vary with the population of the center it supplies.

The value of the coke or semi-coke—as it is more properly termed—depends entirely upon the physical condition in which it is produced. There is no doubt that low-temperature coke, if it is to be used for domestic purposes, must either be produced in a natural, lumpy state, with lumps that are of relatively high density, or if light and porous, that it must be briquetted. This fuel either in a natural lumpy state or in briquet form is a very desirable product. It contains approximately 12 to 15 per cent of volatile matter, is easily ignited, withstands transportation, and is absolutely smokeless. It has all the desirable qualities of anthracite, with the possible exception of density. It has an advantage over the usual grade of anthracite that the householder obtains because of its lower ash content. If we assume that coal under treatment contains 7 per cent of ash, then the finished semi-coke that is produced will contain 10 per cent of ash, and the author seriously doubts whether there is very much anthracite that is now marketed with an ash content as low as 10 per cent.

Price at Which Low-Temperature Coke Should Sell

Large quantities of Carbocoal as made by the International

Coal Products Corporation at Clinchfield, Va. sold at prices net to the plant that varied between $6.50 and $7.50 per net ton. This fuel was subsequently marketed in Chicago at a retail price in the neighborhood of $14. It was the pioneer fuel of its kind in the United States, and naturally it had to be sold at a discount in order to introduce it, but the retail price that was obtained showed the possibilities for this type of product. If we eliminate from our consideration the pioneering years through which a new product must pass, it should be possible—and the author is convinced that it is—for a good low-temperature coke in either briquet or lump form to sell at a price of $10 or $11 per ton f.o.b. plant, provided of course the plant is located close to the point of consumption, and that no high freight rates are involved in its delivery.

Another method of judging its value is to place it on a par with anthracite, and then, in order to have a factor of safety, sell it at a dollar a ton less. Anthracite runs from $8.75 to $9 f.o.b. mine, and retails within 100 miles of the mine for $14. Inasmuch as it is recommended that the carbonizing plants be near large centers of population, then delivery could be made direct from the plant to the consumer, say, at $13, allowing $2 per ton for delivery charges, leaving a net at the plant of $11. In those localities where the price of anthracite runs even higher, that is, $17 or $18 a ton, the net to the plant becomes even greater, or a greater sacrifice could be made to encourage its introduction.

The gas from these processes, when made in an externally heated retort, is of a very rich quality. It is quite common for it to run to 750 B.t.u. per cu. ft., and in some cases as high as 1000. In other cases where the retorts are heated internally, that is, by a combustible gas or by a flue gas, the B.t.u. content varies with the method of operation, but even by this method the gas can be produced with a calorific value running as high as 600 B.t.u.

Naturally there would be a good demand for a gas containing 750 B.t.u. or over that could be blended with a blue water gas and used for domestic purposes, or could be blended with a producer gas and used for industrial purposes. The amount of gas produced will vary with the method of production, as well as with the type of coal being carbonized. As a rule it may be assumed that, regardless of the type of process, the B.t.u. produced in gaseous form amount to approximately three million per net ton of coal treated. If, therefore, a gas of, say, 800 B.t.u. per cu. ft. is being made, we may expect the total production to be in the neighborhood of 4000 cu. ft. or a little less, and if a gas of 500 B.t.u. is being produced, a yield of approximately 6000 cu. ft. There is no question but that the richer gases are the more desirable and that they would be readily purchased by any gas-manufacturing company.

To burn producer gas efficiently requires a high preheat of the air used for combustion. Even if this air is preheated to a high temperature by means of recuperators or air heaters, many heat units are still lost through hot flue gases. This loss can be largely overcome by enriching the gas. One concern is doing it with gasoline—an expensive method—thereby reducing the temperature of the air required and the loss of heat through hot flue gases. The rich gas from low-temperature carbonization could be used very effectively for this purpose.

The cost, under the holder, of 550-B.t.u. gas averages 30 cents per 1000 cu. ft. Uncarbureted water gas or blue gas costs 20 cents per 1000. One cubic foot of blue gas blended with one cubic foot of low-temperature gas is equivalent to two feet of 550-B.t.u. gas. On this basis the low-temperature gas is worth 40 cents per 1000 cu. ft.

The yield of liquid by-products is probably more affected by the type of coal being used than is either the yield of coke or that of gas. Before contemplating the distillation of coal by means of low temperatures, very serious thought must be given to the type of coal available. Inasmuch as practically all of the processes depend upon the yield of by-products for a part of their revenue, it would be illogical to select one that was not potentially rich in tar or oil. It is doubtful whether a coal containing less than 25 per cent of volatile matter should be treated, because the yield of tar would be relatively small; whereas with a coal containing 30 per cent or more of volatile matter, a very good yield of tar can be expected. In some experiments which the author carried out a few years ago and in which the results from 60 different coals were averaged, and where the coal contained in each case at least 30 per cent of volatile matter, the average yield of tar was in the neighborhood of 27 gal. Some of these coals, low in oxygen, gave yields as high as 31 and 32 gal., while those high in oxygen gave yields that were below the average. Setting up the value of the tar, we find that many claim it to be worth only the price of fuel oil, say, 5 to 6 cents per gal.; but let us look at it from a different standpoint, assuming for the present that the producer of the tar is also going to be the refiner, and therefore that the tar costs nothing. A figure of two cents a gallon will probably cover all refinery operating costs. On distillation an average low-temperature tar would yield 60 per cent of oil and 40 per cent of pitch when distilled to a high-melting-point pitch.

Cost Estimates

Pitch in large quantities is usually a drug on the American market except in certain cases such as caused by the recent British coal strike, which also caused a pitch shortage on the other side and resulted in a demand for the American product. But in considering low-temperature carbonization it is necessary to remember that if it is successful it will be successful in a big way, and consequently the quantity of tar will be large—so large, in fact, that the market would be glutted with roofing or paving pitch unless some other use were found for it. The most logical one seems to be as fuel. As a matter of fact it is actually being used as such, being produced with a melting point of 300 deg. fahr. This is pulverized and used as powdered fuel and brings a return of $5 a ton where coal sells for $4.50. In view of the fact that it is practically ashless and contains over 15,000 B.t.u. per lb., this credit is not large. Assuming a yield of 25 gal. of tar per ton of coal, we obtain 10 gal., or approximately 100 lb. of pitch, with a value of 25 cents.

Most of the oil from the distillation of the tar would be utilized in three ways, namely, as wood preservatives, as disinfectants, and as flotation oils. There are many other special fields where in time it would probably find its place, such as in preparations similar to bakelite and as fuel for Diesel engines. It can also be "cracked" for motor spirits and thus acquire an enhanced value. The first three uses are the most important and form the basis of the following calculations. A good grade of wood-preserving or creosote oil is now selling at 16 to 18 cents per gal. in tank-car lots. Disinfectant oil and flotation oils are even higher, bringing 20 to 25 cents, so assuming an average price of 16 cents per gal. may be considered as conservative. With a yield of 15 gal. of oil the revenue therefrom is $2.40. This plus 25 cents credit for the pitch makes a total of $2.65, from which a deduction of 50 cents for distillation charges leaves a net of $2.15, or better than 8 cents a gallon for the tar, and this without considering any of the special uses with higher prices to which the oil may be put.

Compare for a moment low-temperature and high-temperature tar. The former contains nearly 50 per cent more oil and half again as much pitch as the latter. The latter is sold by the producer, usually the coke ovens, at not less than 5 cents a gallon. If this amount is obtainable for high-temperature tar, then certainly the low-temperature product is worth half as much again, if not more.

The only remaining item for which a credit is taken is that of motor spirits. It is quite true that the low-temperature processes produce as much as the coke ovens, and there is reason to suspect they should produce more. With the right type of coal the yield of crude motor spirits will run between 3 and 4 gal. per ton, and on refining will probably yield 2 to 3 gal.—say, $2^1/_2$ gal.—of a product ready for use in automobiles. The last price that the author knows of as being quoted for tank-car shipments of this finished product was 19 cents per gal., so that a credit of at least $47^1/_2$ cents per ton should be taken.

In summarizing the credit side of the operation for a plant carbonizing at least 500 tons of coal a day, the values of the various products have been reduced in order to present a more conservative estimate. This, then, shows the following:

0.7 ton of semi-coke at $10	$7.00
4000 cu. ft. of 800-B.t.u. gas at $0.40 per M ft.	1.60
25 gal. of tar at $0.07	1.75
2½ gal. motor spirits at $0.19	0.47
Total	$10.82

From this deduct $4.50 as the price per net ton of coal, leaving a balance of $6.32 to cover fixed charges, operating expense, and profit. The operating charges other than fixed charges are set up per ton as follows:

Labor	$0.45
Repairs	0.25
Power and light	0.10
Lubrication, etc.	0.05
Fuel for carbonization	0.55
Light-oil refining	0.10
Total	$1.50

Deducting $1.50 from the previous balance leaves a remainder of $4.82, from which must still be deducted the fixed charges. These should not, except with an exceedingly expensive plant, exceed $1 a ton, leaving a final net profit of $3.82 per net ton of coal treated.

The author has not in this analysis of costs and profit taken an exceedingly optimistic view, but has taken one which might be considered favorable to the operation. In order to place the operation on a still more conservative basis, new credits which are considered extremely moderate are taken, and these show the following:

0.7 ton of semi-coke at $8	$5.60
4000 cu. ft. of gas at $0.40 per M ft.	1.60
25 gal. of tar at $0.05	1.25
2½ gal. of motor spirits at $0.15	0.37
Total	$8.82

Deducting the previous costs of $4.50 for the coal, $1.50 for operating charges, and $1 for fixed charges, making a total of $7, there is left a net profit of $1.82 per ton of coal carbonized.

It will be noted that the value of the semi-coke has been taken at $8, or at approximately $1 per ton less than the cost of anthracite at the mine, and it will be further noted that the price of the tar has been reduced to 5 cents per gal., which is as low as the price now prevailing for a good grade of coke-oven tar, and also that the price of the motor spirits has been reduced to 15 cents per gal.

All of the foregoing relates to those processes making a domestic product and producing it without resorting to briquetting.

In the case of the processes making a pulverized product, and particularly in that of the McEwen-Runge process, other conditions enter into consideration. The point has not yet been reached where the results can be intelligently discussed on the basis of performance, and the author therefore prefers not to discuss them at all, except to say that while the profit per ton will probably be less, the scope of the process should be much larger.

Discussion

A. G. CHRISTIE[2] wrote that low-temperature distillation of coal had received much attention in this country during the years and that many exaggerated statements had been made of its possibilities. The frank analysis of the situation presented in this paper was therefore very timely.

During the past few years Professor Christie had had occasion to follow the development of low-temperature processes from a commercial viewpoint. Dr. Runge had briefly described the principles of certain of these processes and the yields to be expected from them. As stated in the paper, the semi-coke was either in a very fine friable state and had to be briquetted, or was in the form of small balls, light in weight, and large in bulk. The latter could be produced much more cheaply than briquettes but would present some stoking problems as a greater bulk had to be fired at a time than anthracite and it would burn out more quickly.

Producers of smokeless fuels must realize that considerable educational propaganda must be carried on to make these fuels attractive to the average householder. The latter would have certain prejudices against coke. He would also have to be taught how to fire the new fuel properly and in certain cases, it might be advisable to modify his furnace or boiler to adapt it to burning semi-coke in a satisfactory manner. In cities where soft coal was burned quite generally, he would hesitate to pay a high price for the new smokeless fuel even though it had social advantages in making his city cleaner. This suggested that it might be necessary to sell the new fuel at a much lower figure than anthracite for some time after its introduction. If such were the case, this factor, and the cost of advertising and educational effort might absorb a large portion of the profits shown in the balance sheets in the latter portion of the paper. The writer believed in the principle of low-temperature carbonization and looked forward to the early adoption on a large scale of certain processes. However, a conservative view of possible profits should be taken and he was convinced that unless conservative figures were used, many people would lose money and faith in low-temperature carbonization.

Dr. Runge had described only a few of the many processes under development. Several other processes seemed very promising and appeared to be approaching a commercial stage. A warning, however, should be sounded against many of the "paper" processes that were being promoted with no further development work than some patent drawings. Experience had indicated that many such ideas did not work out satisfactorily when tried in commercial sized units.

In general Dr. Runge was right in advocating the location of the plant near the consuming center. There might be a few exceptions to this conclusion. The natural-gas supply was failing in certain sections where suitable coal for retorting occurred in quantity. It might be possible that large low-temperature carbonization plants could be built near the mines and the low-temperature gas supply be furnished to the present natural-gas pipe lines. The treated fuel and liquid by-products might be shipped to consuming points at freight rates which would not exceed those on raw coal.

Since the high-heating-value gas from low-temperature retorts had a high intrinsic value for blending and mixing with city gas, it would appear that the retorts themselves should be heated either by producer gas or by blue water gas.

Dr. Runge's values for tar seemed reasonable at the present stage of development. Much was being learned abroad about the hydrogenation of various materials and the catalysis of mixtures. One could imagine that a method might yet be found by a combination of hydrogenation, catalysis, and cracking to produce much larger quantities of the high-priced light oils suitable for motor fuels from the heavy oils and pitch. However, if the prices quoted in the paper for cresote, disinfectant, and flotation oils could be maintained, it might not pay to attempt to convert these oil portions into motor fuels.

The writer felt that the paper would form a valuable contribution to the literature of the subject. Dr. Runge had rightfully directed attention to the economic rather than the theoretical side of this development, for there was a danger that these new processes very easily might be ruthlessly exploited by financial promoters.

In answer to a question about the ease of ignition of pulverized coke in a steam-boiler furnace, R. P. Soule,[3] who presented the paper in the absence of Dr. Runge, said that in the furnace at the Lakeside plant of the Milwaukee Electric Railway and Light Co. the coke was ignited by a torch in the same manner which pulverized coal was ignited.

The coal used at Lakeside, he said, in answer to a question by Wm. L. Abbott,[4] was from western Pennsylvania. The volatile varied from 30 to 35 per cent, averaging 33 per cent. It was dry before pulverization and came to the hopper with about 1.5 per cent moisture. The loss through the primary retort was about 1 per cent. Through the secondary retort the loss in volatile was a matter of operating conditions and could be reduced to any point between 5 and 15 per cent. The 10 per cent volatile which remained would yield practically no tar. He did not know how coke with 25 per cent volatile would flow, but the production of it would be impractical economically because of the low yield in gas and tar.

[2] Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.

[3] International Combustion Engineering Corporation, New York, N. Y.

[4] Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill. Past-President, A.S.M.E.

Protection of Flour Mills and Grain Elevators Against Fire and Explosion

By F. J. Hoxie,[1] Boston, Mass.

Flour mills and grain elevators have a bad reputation as insurance risks, due to the fact that the explosions to which they are subject are not controllable by automatic sprinklers. As common methods of automatic protection are powerless, new methods must be devised. Laboratory experiments, as well as study of recent large elevator explosions, demonstrate that grain-dust explosions are slow compared with those of gasoline or gunpowder, therefore they may be relieved by automatically opening windows or shutters, provided that the latter open easily and have sufficient area compared with the volume of the room to be protected.

The fine particles which cause the most rapid explosions can be removed from the atmosphere where they originate and thereby be prevented from accumulating over a period of years on the inside of elevator enclosures and pulleys, and in other out-of-the-way places.

The bad explosions which have occurred recently in modern concrete elevators have been in those with open-top grain tanks. This arrangement presents an immense undivided volume of air without cut-offs, in which the pressure, caused by the confined heat from the rapid combustion, can build up to a large amount when there is no provision for relieving it.

The supports of these elevators are not designed to stand a horizontal thrust, therefore a comparatively small explosion pressure in an enclosed basement with small vent openings can push the foundations from under heavy tanks, causing a serious wreck.

With air suction on all of the conveying apparatus and enclosures in which fine dust is formed, self-opening shutters or windows throughout, together with modern concrete construction, closed-top tanks with automatic vents, well-vented basements, and other safety appliances now being introduced, the grain elevator or cereal mill can be made as safe as cotton factories with automatic sprinklers. The automatic vents provide the automatic explosion protection which has been the cause of the success of the automatic sprinkler in fire protection, as this automatic feature can compensate for temporary shortcomings of management.

It has long been recognized that the velocity of combustion of structures is dependent upon the size of the supporting timbers, hence the good reputation enjoyed by so-called "slow-burning construction" in which all of the supporting beams and columns are of large cross-section. Such heavy beams are difficult of ignition and burn slowly when ignited, due to the small amount of surface exposed to the oxygen of the air. Continuing this line of reasoning, it is easily recognized that small sticks of wood can be readily ignited by a match. Fine shavings will cause an explosion in a house furnace, and it is to be expected that the rapidity of the fire or the velocity of the explosion (as the difference between fires and explosions is simply a question of velocity) will continue to increase as the particles are made finer. This can be demonstrated in the laboratory by experiments in which dust from elevators and corn starch is exploded in an atmosphere of pure oxygen.

Corn starch, with an average diameter of six ten-thousandths of an inch, gives an explosion pressure of five or six pounds, while fine elevator dust found on the inner surface of pulleys, see Fig. 1, has an average diameter of a ten-thousandth of an inch or less and gives a pressure of nine or ten pounds. The importance of the size of the particles was clearly demonstrated recently in connection with hard-rubber grinding. Dust that is ground by roller mills has been handled by some of the hard-rubber factories for twenty years or more without explosion. It contains practically no dust less than a thousandth of an inch in diameter. Ball mills were recently introduced for this process, and immediately explosions began. A considerable part of the product of the ball mills is a ten-thousandth of an inch in diameter or less. This fine dust, similar to grain dust of equal fineness, adheres tenaciously to the walls of flues and enclosures in which it is handled. An air blast is of little use in removing such fine dust from a surface to which it has become attached. Inert gas from the smokestack, from which the oxygen has been burned, was introduced for conveying this rubber dust in place of air, and the explosions ceased.

Photomicrographs of the finest rubber dust from the roller mills and also from ball mills are shown in Fig. 2. The finest rubber dust gives an explosion pressure in pure oxygen of 14 lb. per sq. in.

It can easily be seen that a process involving so much handling and such a large number of siftings as is carried on in flour mills and the dust containing starch particles much less than a thousandth of an inch in diameter, if not carefully protected, can distribute a large amount of dangerously fine dust into the atmosphere.

In past years when some bad explosions occurred in flour mills, much of this sifting was done in imperfect enclosures with no pretense of keeping the dust out of the air. This dust is flour, and if allowed to escape into the air and be carried away by it, an appreciable percentage of the product of the mill is lost; therefore there is a strong commercial incentive to care for this dust in addition to considerations of safety.

All Dust-Forming Processes Now Enclosed and Under Suction. As at present operated, all of the grinding, sifting, and elevator heads, as well as chutes through which the various parts of the grain flow by gravity to processes on lower floors, are provided with small, well-fitted enclosures, and the entire system is under a slight air suction by means of which the flour is not only kept out of the air of the room but is kept clean and returned to stock. This suction system is doubtless one of the most important factors in the recent improvement of the hazard in flour mills, corn-starch factories, and other grain-working industries.

Pumping Powdered Coal and Corn Starch as a Safety Measure. A method of transporting powdered coal and corn starch about the factory by pumping it through iron pipes instead of carrying it by means of bucket elevators and screw conveyors, would seem to have valuable possibilities for increased safety in keeping the dust out of the air and avoiding large dust-covered conveyor boxes through which an explosion can be conveyed for considerable distances.

Construction of Flour Mills. There are three types of construction in common use. The older mills have brick walls and joisted floors. There are doubtless many small wooden mills distributed throughout the country. The protection of the older type of joisted-floor mill should be very carefully studied. Such a mill will have much of the accumulated fine dust of past years in every crack or crevice of the floor boards and joists, and also adhering to their large surfaces, and it will be more difficult to keep clean. With the accompaniment of numerous small wooden boxes used for bucket elevators and chutes piercing the floors throughout, as well as many unprotected floor openings, a quick fire opening many sprinklers is to be expected, for which a large water supply immediately available, preferably from a large tank, is desirable. Such a mill at best is more hazardous than the concrete and plank of timber mills, although a carefully managed mill of joisted construction can probably be made reasonably safe by being thoroughly protected by automatic sprinklers with large water supplies, and by being provided with inert gas or automatic vents in all enclosures, chutes, and conveyors.

Areas and Floor Openings. An important feature in flour-mill construction from a fire-protection standpoint is the small areas involved. The largest areas in the manufacturing rooms of many of the mills up to 3000 bbl. capacity are not over 4000 sq. ft. This offsets somewhat the large number of small conveyors which pierce the floors, but as these conveyors are tightly enclosed, the floor openings to accommodate them are not so hazardous and are no larger than the numerous small belt openings familiar in textile mills. The mills are heavily constructed and most of them are

[1] Engineer, Inspection Department, Associated Factory Mutual Fire-Insurance Companies.

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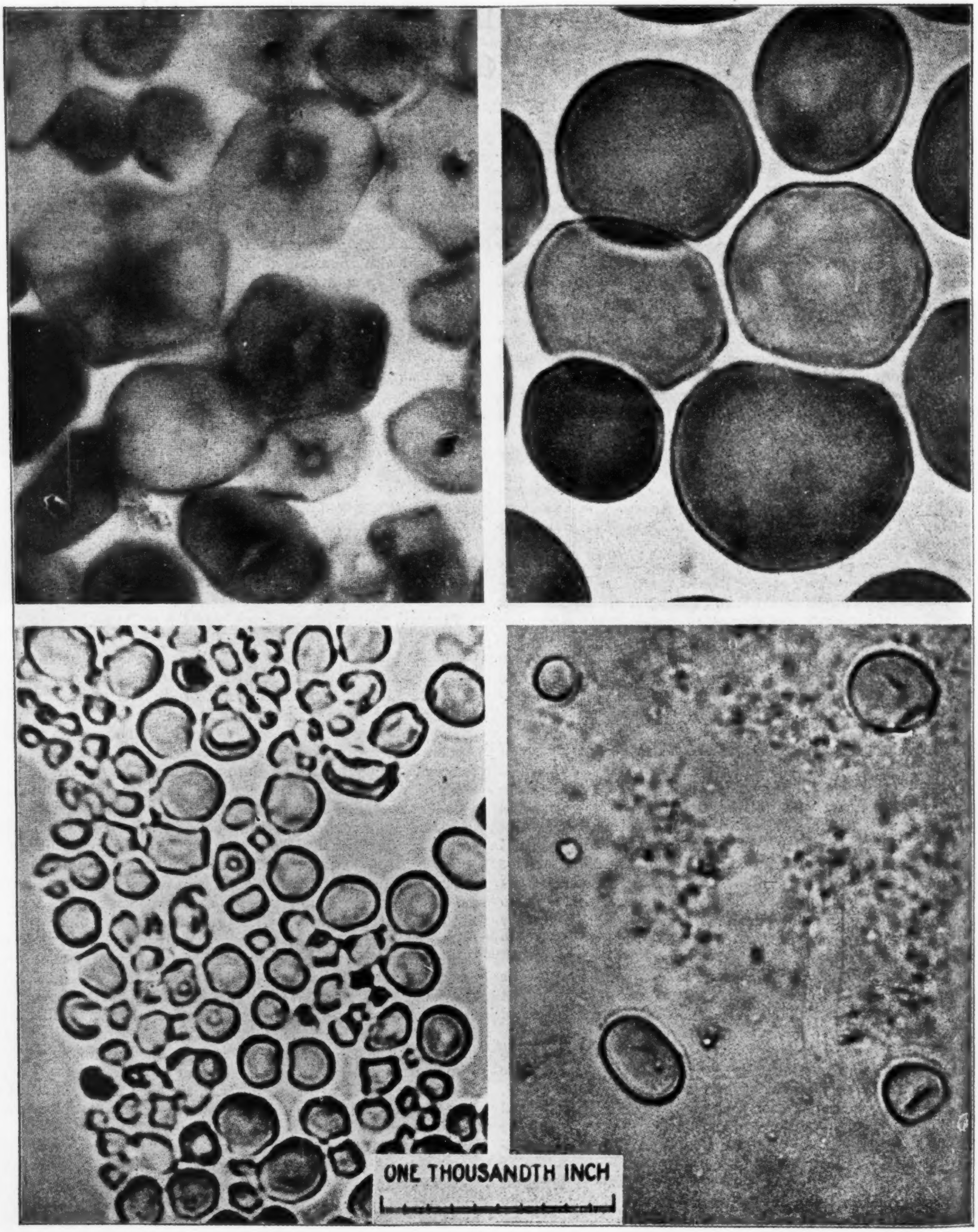


FIG. 1 PHOTOMICROGRAPHS OF COMMON ORGANIC DUSTS ALL AT THE SAME MAGNIFICATION

Top—Corn starch. Note uniformity of the size of particles.
Bottom—Smallest starch granules from wheat flour.

Top—Largest starch granules separated from wheat flour.
Bottom—Finest particles in wheat flour together with a few of the smallest starch granules.

comparatively high, that is, 60 to 80 ft. This is to accommodate the placing of one process above the other so that the material, after being elevated to a sifter, can flow back to the next grinding machine and the flour can flow to the bolters; therefore there is absolutely no handling of grain, bran, or flour in the open atmosphere, with the resulting dust hazard.

As an automatic protection against explosion damage in case suction or cleaning apparatus should be out of repair temporarily,

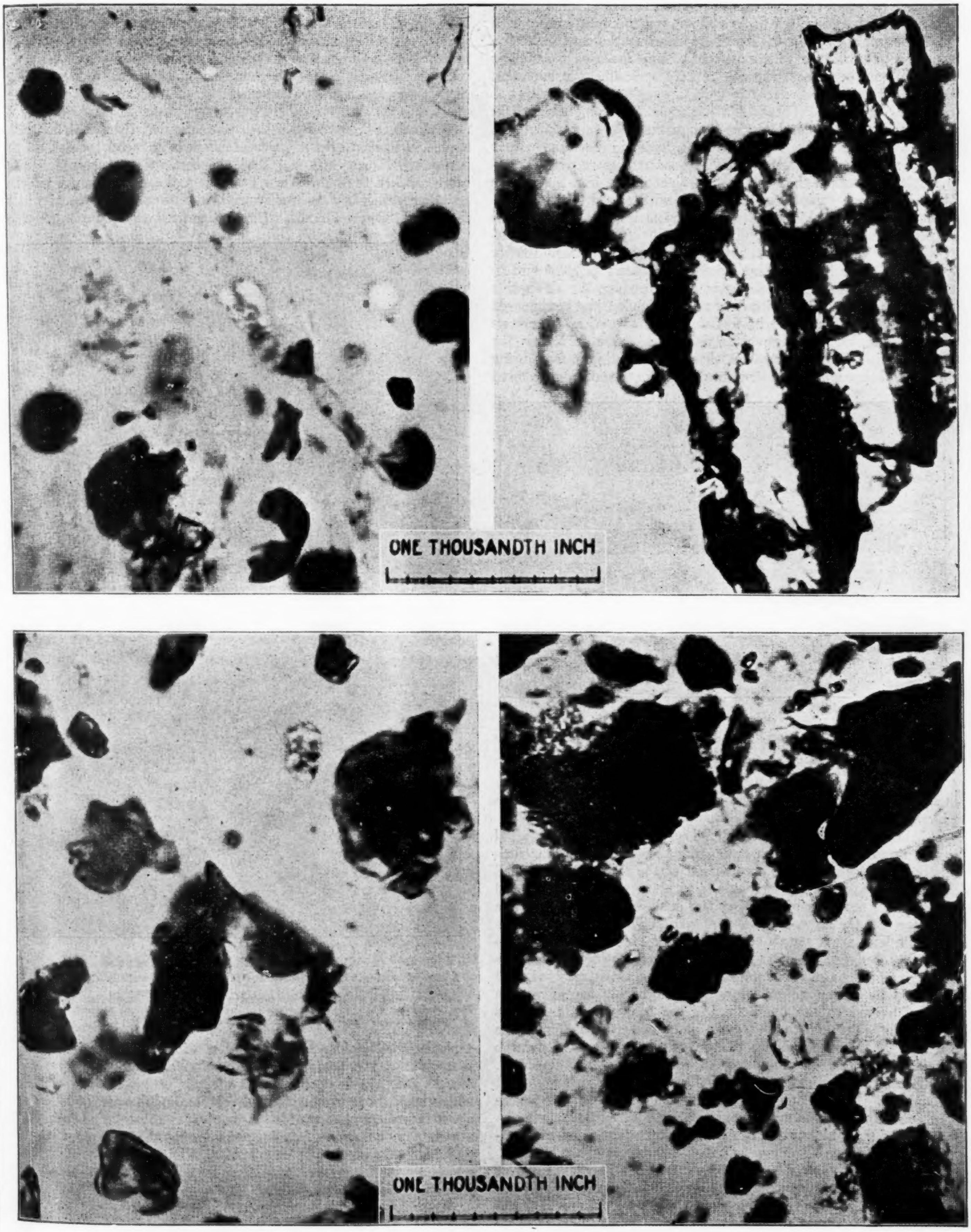


Fig. 2 Photomicrographs of Dust

Top—Dangerously fine dust taken out by the Katy elevator cyclone.
Bottom—Coarse rubber dust from roller mills in which few explosions have been experienced.

Top—Common coarse elevator dust which has weight but is not very explosive.
Bottom—Explosively fine rubber dust from ball mills in which explosions are common.

self-releasing windows should be considered throughout flour mills.

Small openings through walls or floors are more important with dusty occupancies than with ordinary fires as the dust explosion causes a gas pressure which can pass from one area to another through small openings, thereby rapidly spreading the explosion throughout.

Closed Tanks and Small Air Volumes Important Factors in Elevator Explosions. It looks as though the open-top grain tanks were an important, if not *the* important, factor in the three or four serious elevator explosions which have occurred in modern incombustible elevators within the past few years (see Fig. 3). While there have been explosions in elevators with closed tanks, for instance, the recent one in Montreal, one in Baltimore, and a previous one in Montreal, the loss has been comparatively small, and the experience at Montreal indicates that this could have been mostly avoided if there had been self-releasing windows (Figs. 4 and 5) or similar automatic vents throughout. Moreover, the air suction mentioned in connection with flour mills which has just commenced to be applied to the large bucket elevators, as well as to garners and grain tanks, will remove the dangerously fine dust from the conveyors in which it is created, thereby preventing it from being distributed throughout the structure, adhering to walls and secreted

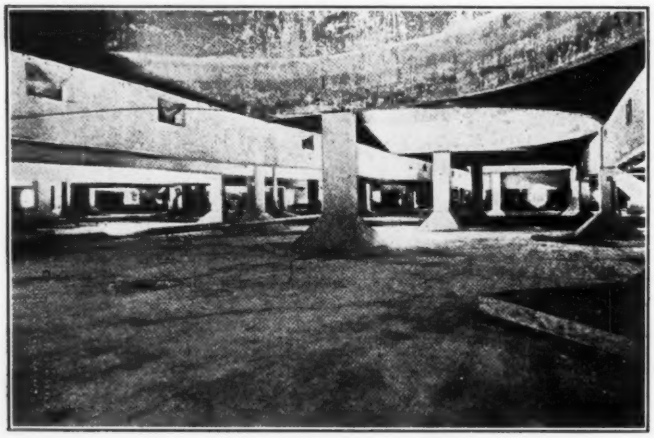


Fig. 3 Open Grain Tanks

(Interior of an elevator containing open grain tanks. These tanks are about 100 ft. deep and when connected by the open space above them, form an enormous air volume filled with readily combustible dust through which an explosion can be propagated with great violence.)

in all of the out-of-the-way spaces ready to cause a serious explosion when dislodged by any unusual commotion such as a small fire.

It is becoming apparent to the Boards of Trade, who have objected to the removal of dust from grain, that this very fine, dangerous dust constitutes so small a proportion of the total grain handled that it is practically unweighable, and as a matter of practical fact, present methods of allowing the dust, both coarse and fine to escape into the atmosphere and be carried by the wind out of the open windows are a source of far more loss of weight than an intelligently designed suction system by means of which the dust is taken out of the elevator enclosures as the grain is received, and separated by a cyclone collector, the fine, highly explosive dust being delivered to the open air and the coarse, non-hazardous dust being returned to the grain in which it came into the elevator. This practical use of the suction system in a large terminal elevator is at once apparent on visiting one so equipped. The floors, walls, ceilings, and all of the apparatus are free of dust throughout. Little hand sweeping, which has been the source of serious explosions as well as of large constant expense, is necessary, as the dust does not escape into the atmosphere and the comfort of the employees is increased, as well as the safety.

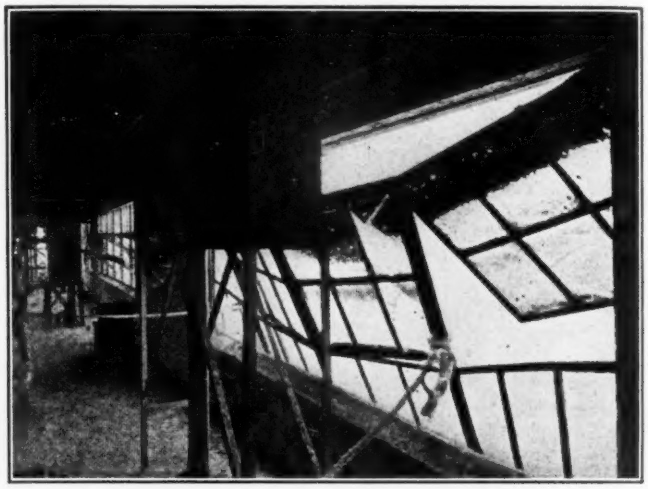
In the small elevators connected with flour mills the Board of Trade requirements as to removing dust do not apply as in commercial elevators, but the removal of the dust is of practical importance to the operators of the mill as it is necessary, sooner or later, to clean the grain thoroughly before admitting it to the grinding apparatus.

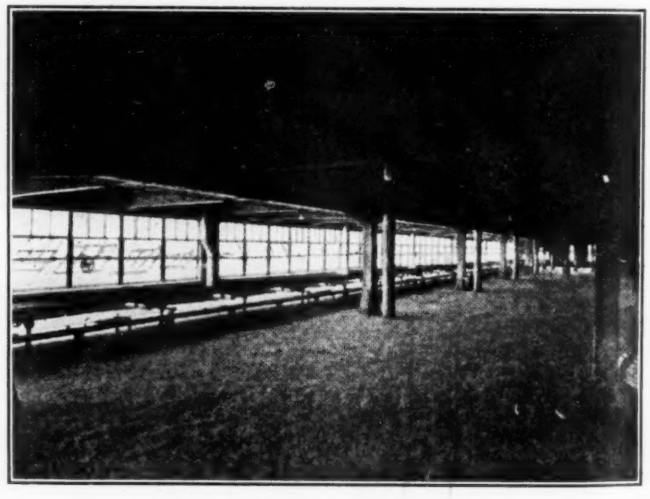
This use of suction in grain elevators is more recent than in flour mills as the commercial value of the dust removed is much less.

There is now being introduced in the modern elevators, particularly the large ones, apparatus which will automatically shut off the grain from the so-called "boot" at the bottom of the bucket elevators if it becomes overloaded and causes the elevator belt to slip. Serious explosions have originated from this source.

Special Hazards

Protection Against Fire. The protection of risks with a dust-explosion hazard cannot be accomplished by means of automatic sprinklers, due to the fact that the combustion takes place far more quickly than sprinklers can act, and frequently wrecks the building sufficiently to break sprinkler pipes and destroy the usefulness of the sprinklers in extinguishing fires which may follow the





Figs. 4 and 5 Self-Opening Windows

Above—Common windows forced out of the concrete wall by the explosion in the Montreal elevator.
Below—Room above the grain tanks in the Harbor Commission Elevator in Montreal after the explosion. Note the self-opening windows opened by the explosion which they vented, and thereby prevented loss.

explosion. Therefore the protection of these risks is divided sharply into two parts: first, protection against explosions, and second, common fire protection by means of automatic sprinklers where such protection is needed for combustible construction or occupancy. The fire protection required is not different from that now in common use in familiar risks, except that the pipes should be securely fastened to the more substantial parts of the structure, which are strong enough and so arranged as to withstand an explosion of moderate magnitude.

Protection Against Explosions. Dust-explosion protection is a new problem. It has been successfully solved in connection with hard-rubber grinding. We now have it before us, not only in connection with grain dust, but in paint spraying in automobile factories, milk-powder manufacturing, cork grinding, and in power plants using powdered coal.

The velocity of the explosion is an important factor in the solution of this problem. An extended series of experiments has already been carried on in a small way in the Factory Mutual Laboratories, and in a larger way in the small test house in Everett, Mass. (Fig. 6.) These experiments show that while the pressure which may be obtained from an explosion of fine dust is sufficient to wreck a substantial structure, the velocity at which this pressure is generated is sufficiently slow to make it possible to relieve it by means of self-opening mechanical shutters or windows, provided that their area is sufficient in comparison with the volume of air in the building.

It is possible to control these explosions by slightly reducing the amount of oxygen in the atmosphere. This is impractical in manufacturing rooms, but has practical possibilities, when used in connection with self-operating shutters, for extinguishing smoldering fires in grain storage tanks, thereby preventing damage by water to the grain. Experiments at the Factory Mutual test house at Everett have demonstrated that smoldering not only in grain dust but in textile fibers can be extinguished by burning half of the oxygen out of the air which is admitted gradually to an enclosure as it cools off after an explosion.

Explosion Prevention. It is more important from all considerations to prevent a loss than to protect against it—although reliable protection must be provided—therefore the first care is to prevent explosions.

As already shown, the very fine dust is the most important factor, and its removal as soon as formed is fundamental in preventing explosions later from dust allowed to accumulate for years in a structure. Therefore an intelligently designed air-suction system on all conveyors and enclosures in which dust may be formed is fundamental. In connection with public elevators where the removal of heavy dust is objected to by the local Board of Trade, this dust may be passed through a cyclone extractor, the heavy and the less explosive dust being returned to the grain with which it was brought in and the light dust discharged into the atmosphere.

Facilities should be provided for the ready inspection and cleaning of enclosures containing bucket elevators. In some of the modern elevators this enclosure instead of being a steel box is a room large enough to contain both sides of the bucket elevator and admit of containing also ladders or stairways by which it can easily be examined and, when occasion requires, brushed down. This is desirable even though a good suction system is supplied, as is shown by the accumulation of fine dust on moving pulleys. After a long time, probably years, the action of the wind circulated by the rapidly moving buckets will tend to separate out the finest and most explosive dust and fasten it securely to the walls of the conveyor enclosure. The smoothness of these walls is of little importance, as such fine dust can be readily made to adhere to a glass plate under the action of a high-velocity air current.

Bucket-elevator enclosures should be provided with a self-releasing skylight at the top which, in case of explosion, can open the entire top of the enclosure, allowing the pressure to vent itself high in the open air.

All windows in elevators and other enclosures where dust may accumulate should be made self-releasing so that they can be easily pushed open by a slight explosion pressure, thereby venting the explosion at once where it originates and not allowing it to push back into the structure and extend throughout.

Relation of Vent Area to Volume of Room to Be Protected. A large number of experiments carried out by the Factory Mutual Laboratories in a small test house show that with grain dusts, or other fine organic dusts such as starches, a vent area of one square foot for every fifty cubic feet of volume of air in the room to be protected will safely relieve the pressure. With materials which explode more rapidly, such as gasoline and the common volatile solvents, this proportion should be in the neighborhood of one square foot of vent area to every ten cubic feet of volume.

To check the results in the small house, other experiments were carried out in a larger building (see Fig. 6) with 15,000 cu. ft. of volume and using 140 lb. of dry corn starch for the dust cloud. These explosions showed that the above proportion of vent area to room volume also holds for the larger building.

Grain tanks and similar tight bins and enclosures should be provided with large self-opening shutters which will readily vent an explosion within and, closing immediately afterward, hold in the inert atmosphere formed by the explosion, thereby extinguishing any fire which may remain, without the use of water. Such tight tanks or enclosures should also be provided with means of introducing air from which at least half of the oxygen has been burned by means of oil or other convenient fuel. Where a smokestack from a boiler is available, inert gas can be taken from this, provision being made for cooling and cleaning it. This is of particular importance in connection with the storage of feed or textile fibers, which readily smolder. The object is to continue to supply inert gas as the drop in temperature in the tank reduces the volume of the atmosphere contained, which would otherwise draw in air and keep up the smoldering. The amount required will not be large in a grain tank. When only grain is kept in the tanks, probably none will be needed, as this does not smolder.

A Small Reduction of the Oxygen in the Atmosphere Will Prevent Dust Explosions. Experiments were made in the test house (6 × 8 × 8 ft.) by burning various percentages of the oxygen out of the air, and it was found that when atmospheric air normally containing 20 per cent of oxygen had this amount reduced to 17 per cent, dust explosions were prevented. With 15 per cent, flaming fire can be prevented, but fibers (such as cotton or jute) and grain dust will

Fig. 6 Everett Test Station—Factory Mutual Laboratories

(An explosion taking place in a galvanized-iron building containing 15,000 cu. ft. of air. The explosion was caused by a dust cloud of 140 lb. of dry corn starch. The dust cloud was being maintained by overhead rotating sieves and a large blower. Note the self-opening doors and shutters, opened by the explosion and the starch dust escaping. The proportion of vent area to air volume in this building was 1 sq. ft. of vent area to 50 cu. ft. of air volume. The building was not damaged by several such explosions due to the protection afforded by the self-opening vents.)

continue to smolder until the percentage of oxygen in the atmosphere is reduced to less than 10 per cent. With only 7 or 8 per cent of oxygen, even smoldering is prevented.

Clumping and Adhesion of Fine Dust to Walls of Enclosures. Dust of the magnitude of from one to three ten-thousandths of an inch in diameter shows a strong tendency to clump together and to attach itself to walls of enclosures so securely that it is difficult to dislodge it without rubbing or brushing. The smoothness of the wall or an air blast appears to make dust of this fineness stick to the wall more tenaciously, whereas slightly coarser dust of from five ten-thousandths to one-thousandth of an inch in diameter can be dislodged by an air blast.

Recommendations

The following general recommendations should be carried out to prevent explosions in grain elevators, cereal factories, and starch factories.

1 Automatic sprinklers should be provided in all buildings of combustible construction or occupancy, such as dry buildings with wooden floors or dry combustible storage.

2 At intervals of about a week, brushes should be run through the bucket-elevator housings so as to remove any fine dust adhering to the walls. At the same time the suction should be kept in operation so as to remove this fine dust as rapidly as it is released. The suction alone without the brushing will not remove it, as under the influence of the air blast caused by the revolving buckets the very fine dust is separated and fastened to the walls of the conveyors.

3 All elevators or other enclosures in which dry starch is handled

or dust is made should be provided with air suction, and provision should be made for brushing off the dust on the inside of such enclosures.

4 All elevators in which dry starch or grain is handled should be provided at the top with a steel vent pipe communicating with the open air and arranged with a self-releasing cover so that in the case of an explosion in such pipes it will be vented to the outer air where it can do no harm. The object of this is to take care of an explosion caused by any lack of care in keeping the inside walls of such elevators free of dust. The area of the vent opening should be at least 1 sq. ft. for each 50 cu. ft. of atmosphere in the enclosure.

5 The rooms at the top of corn elevators and all other rooms in which dry organic dust may accumulate should be provided with self-opening windows so arranged that they will open in case of an explosion, closing again when the explosion wave has passed, keeping in the inert atmosphere formed by the explosion and thereby preventing a second or third explosion, which is the common experience. Our experiments have shown that if the atmospheric oxygen is reduced to a little less than 17 per cent, explosions are prevented. To maintain such an inert gas in a room at all times would be somewhat troublesome and expensive, but if it can be so arranged that the first explosion produces this inert atmosphere, such inconvenience can be avoided.

6 Openings in floors of buildings of dusty occupancy should be avoided so that the explosion waves can be confined to the place where they originate and be vented to the outer air, thereby preventing large loss of life and property. All dust-explosion vents should have a superficial area of one (1) square foot for every fifty (50) cubic feet of volume of the room protected.

7 Rooms in which it is necessary to provide sprinklers to protect against a fire hazard and which also have an explosion hazard, should have the sprinkler pipes securely fastened to the supporting beams of the structure, not to the flooring between these beams as is customary in common sprinkler installations. The object of this is to prevent an explosion in the early stages of a fire from breaking the sprinkler pipes and putting the sprinklers out of commission.

8 All machines handling dry starch or other dusty material and supported on wood should have their metal parts securely grounded to the pipes in the building.

9 In some of the corn-starch factories it has been noted that outside stairways have been provided to avoid openings between floors. This is an excellent plan, but in order to make them effective as a life-saving device they should not pass in front of windows which are to be used as doorways for gaining access to the stairways, as when this is done the same results are probable as in the Ashe Building fire in New York some years ago, in which the fire occurred on one of the floors below the top of the building and when the occupants of this floor opened the windows to the fire-escape the fire followed them out, heating the ironwork of the latter and cutting off escape for those in the upper part of the building.

Discussion

HYLTON R. BROWN[2] wrote that he was familiar with the work being done by Mr. Hoxie, particularly at the Everett testing plant of the Associated Factory Mutual Fire Insurance Companies and felt that some important determinations of the value of methods of preventing dust explosions had been made at this plant. As far as known the experiments made at the Everett testing station to determine the value of automatic sash venting devices for the release of explosion pressure were the first large-scale tests of this kind made in this country and the results, certainly justified the fullest consideration of this method of preventing damage by dust explosions.

It was hoped that Mr. Hoxie would elaborate somewhat on his statements showing the effect of particle size on the explosion pressures produced. It was assumed that the pressures given for corn starch and fine elevator dust were relative pressures only and based on tests conducted with certain standard or uniform quantities of dust, since the maximum pressures evidently occurring in some factory explosions were in excess of the figures given. As a result of investigations made following disastrous dust explosions it has been estimated that pressures of 300 to 400 lb. per sq. in. would be necessary to cause the damage observed.

Mr. Hoxie had given many helpful suggestions for the protection of plants both against fire and against explosion as well as suggestions for the prevention of explosions. In the present stage of development through which many suggested methods of dust-explosion prevention were passing it was still well to provide protection against damage to the plant from the explosion which might occur, and at the same time keep in touch with the development of the various prevention measures. Perhaps the method of dust-explosion prevention which held the greatest promise at the present time was the use of inert gas. Experiments have demonstrated beyond a doubt that it was possible to prevent both fires and explosions in this way but they had also shown that the reduction of oxygen necessary to prevent combustion would vary for different materials. For instance, to prevent a sulphur-dust explosion it was necessary to limit the oxygen content to 8.0 per cent. A number of plants had already installed inert-gas equipment to prevent explosions and others were considering making such installations. In all such cases it was advisable before designing or installing such equipment to obtain definite data on the amount of inert gas which it would be necessary to use to prevent ignitions or explosions of the material being handled. Such data were being compiled as rapidly as possible through laboratory and experiment-station tests.

R. E. Greenfield[3] wrote of some of the precautions being taken by the A. E. Staley Manufacturing Company, which is engaged in the manufacture of starch gluten feed, and other products from corn, to prevent dust-explosion accidents.

The methods in use could be divided into two classes: First, those designed to prevent the formation of dust clouds and the accumulation of fine dust in exposed places and to segregate dangerous materials in such a way as to give no opportunity for their ignition. Most of these methods had been covered by the paper. Second, those designed to prevent the formation of sparks, flames, or heat which might ignite the inflammable material and thus initiate the explosion.

The first class included the following:

a A suction system of collecting dust from all dusty processes. All conveyors, elevators, both heads and boots, dumping hoppers, reels, bins, etc., receiving or handling dusty materials, were covered and connected to suction fans which drew off the dust and discharged into suitable dust collectors. The most successful of these dust collectors was a wet system making use of a gyrating spray.

b Thorough cleaning to remove all accumulation of dust. The floors, walls, beams, and machines were swept and cleaned continuously. Moving machinery such as motors, pullies, shafting, etc., was shut down and cleaned at regular intervals. As mentioned by the paper the suction system greatly reduced the amount of cleaning necessary.

c Air humidifying. Air furnished in some of the more dusty departments was humidified, thus preventing the drying-out and floating of any accumulation of fine dust.

d The elimination of screw conveyors and low-pressure air conveyors and substituting in their place high-pressure Fuller-Kenyon conveyor systems, referred to as "pumps" in the paper. Screw conveyors were dusty and often develop hot boxes in intimate contact with the dry product. Low-pressure air or suction conveying formed a cloud or a low-concentration mixture of air and dried product easily ignited, both often constituted connections between several buildings along which fires or explosions might travel. The Fuller-Kenyon system made use of less air with the production of less dust. The conveyor between buildings was small and filled with an air-product mixture which, in the first place, was traveling so fast that a fire could hardly travel in a counter direction and, in the second place, the concentration of inflammable material was so high that a fire would soon smother from lack of oxygen. This system was now being used on dry and pearl starch and was being experimented with on dry feed.

As a fire protection all the departments were equipped with sprinklers; fire hydrants were located at strategic points. Water

[2] Assistant Development Engineer, United States Department of Agriculture, Bureau of Chemistry, Washington, D. C.

[3] Research Chemist, A. E. Staley Manufacturing Company, Decatur, Ill.

was furnished from an elevated tank, and hose and hose carts were maintained by the factory.

In the second class were the following preventative methods:

a Prevention of static accumulation on belts and machinery. When first investigated the building up of static charges on moving belts had been found to be serious. Long sparks could be drawn from many belts and luminous discharges could be seen on some at night. The first surveys of the belts were made with a neon tube provided with several fine wire "whiskers" to serve as a collector. With this tube some idea could be gotten as to the magnitude of the charge from the brightness of the discharge, and charges down to about seven hundred and fifty volts could be detected. Later an electrostatic voltmeter with a range from four hundred volts to ten thousand, graduated in units of one hundred volts, was purchased and used in further surveys and in the regular weekly inspection now made of all belts.

Various experiments with comb-like static collectors, horizontal wires, and systems of wires were made in an attempt to remove this static with varying degrees of success. A glycerine preparation was tried on the inner surface of the belt. This was efficient but caused increase slippage and was expensive and difficult of application. Finally a brush made up on a metal back consisting of a great number of very fine wire, i.e., 36 gage, was developed. This brush was made by unraveling a stranded wire cable containing four hundred and thirteen strands. Two cables are unraveled for each inch width of brush making the brush have over eight hundred collecting points to the inch. The brush was made the full width of the belt, was supported in such a way as to sweep usually the upper outside surface of the moving belt, and was grounded to the water system or some other good ground. Usually one brush was sufficient but at times two were used on the upper outside surface and sometimes a second brush was made to sweep the inner surface. No successful method had been developed of applying them to the lower surfaces of the belts. The position with relation to the machines was often fixed by convenience but at times the position was important and had to be changed until satisfactory results were obtained. These brushes must bear on the belt and must not be knotted and snarled as the existence of many collecting points seemed to be the important factor. Worn or badly snarled brushes must be replaced. In this plant all brushes were inspected daily and weekly measurements were made of the static voltage on all belts. This system had virtually done away with measurable static on belts. A so-called non-static composition belt was being experimented with, but no definite results as to its success could yet be reported. In addition to the elimination of static on belts, extensive grounding of other machines was necessary. All reels, metal suction or conveyor pipes, mills, and any other machinery showing the need of it were thoroughly grounded either by this company or by the manufacturer of the machine.

b Protection of electric fixtures. Fuses, switches, and any electrical device throwing sparks at any time in its operation were enclosed dust tight. Lights were enclosed dust tight to prevent accidents from breakage. These precautions were a logical extension of the static prevention work.

c Lubrication was in charge of one man, and was kept at a high point of efficiency. This greatly reduced the danger of hot bearings.

d Soft non-sparking grinding surfaces. Certain starch mills were made of bronze to prevent striking sparks on any hard objects which might get in by accident.

e Policing of factory. Non-smoking rules were enforced and carrying of matches prohibited.

W. F. Canavan[4] gave some statistics of dust explosions and pointed out how the menace had increased with the substitution of bomb-like structures of concrete for the wooden-cribbed elevators which, while subject to destruction by fire, were better vented to prevent explosion hazards. His experience had centered around the use of self-opening sash and the control of them, and he was firmly convinced that it was impossible for a destructive explosion to occur in a properly vented house. The vent area should be in proportion to the capacity of the structure, and while Mr. Hoxie advised a ratio of 1 sq. ft. for every 50 cu. ft., he felt that 1 sq. ft. per 100 cu. ft. was sufficient.

[4] Canavan Explosion Venting Systems, Montreal, Canada.

The self-opening sash were pivoted several inches down from the top and were about 3 ft. 6 in. square. They are operated in runs of five to seven vents on one horizontal shaft controlled from an operating station preferably located about the center of the run. The sash were readily opened up to 90 deg. or held closed. The holding friction could be adjusted so that a horizontal pressure of from practically nothing up to, say, 100 lb. would be necessary to open the sash. Evidently these sash would open long before destructive pressures occurred in the structure.

It had been determined through Mr. Hoxie's tests at Everett and his own at Montreal and in actual dust explosions that the pressures, when released at their inception, were strong enough to operate the automatic vents and that once the vents were open the force of the explosion was dissipated. It was safe to say that once the building was opened at low pressure, there was no secondary burst or propagation. Also it had been found that in releasing the pressure at the point of origin the explosion was localized and its propagation through the structure prevented.

M. D. Bell[5] spoke of the flour-mill explosion in 1878 in Minneapolis and the subsequent investigation and litigation. He believed that a modern dust-collecting system was primarily to be relied upon to eliminate dust before it could settle and that the building should be constructed with just as few ledges as possible.

In closing the discussion, the author said that the insurance companies with which he was connected had insured cotton mills for years and in these, automatic sprinklers had been the salvation. In such mills, where dust-explosion hazards were first considered, it had been customary to put in a regular cotton-mill protection. A cotton-mill equipment in a flour mill or grain elevator was almost, if not quite, worthless for the reason that the explosion was so much more rapid than common combustion that the sprinklers did not have a chance to operate at all, or the pipes which supplied the sprinklers were broken by the destruction of the floors at the first part of the explosion.

The reason that automatic sprinklers had been successful in cotton mills was that they were automatic. They took care of lapses in management. If the mill were kept perfectly clean and everything were properly taken care of, there would be no fires. There was always a time in almost any mill when there was a lapse. The automatic vent in the dust explosion took the place of the automatic sprinkler in the fire risk and it compensated for any lapse in management. If the mill were not kept clean, the automatic vent would relieve the pressure and prevent serious loss just as the automatic sprinkler opened when the cotton was allowed to accumulate and got on fire.

How rubber articles are produced electrically by a method like metal plating was described recently at a meeting of the Detroit section of the Society of Automotive Engineers by the inventor of the process, Dr. S. E. Sheppard, of the Eastman Kodak Co.

The process consists in passing an electric current through a mixture of rubber latex, or uncoagulated milk of the rubber tree, with water, sulphur, fillers, accelerators, softeners, and other materials, according to the various requirements of the article to be produced. The particles of rubber and other materials become charged electrically and are deposited together on molds of the desired shape, the same as copper or nickel is deposited on metal articles when plating. When the mixture of rubber and other ingredients is electro-deposited, the composition remains substantially unchanged during the coating, and the resulting rubber is of the same composition as the solution. This is essential to the success of the process, because the rubber compound produced must be similar to rubber produced by the mechanical masceration and compounding method. Rubber is much easier to deposit than nickel, for with the same amount of electric current a coating 1400 times as thick as nickel-plating can be deposited.

Rubber produced by the process has greater strength, toughness, and resistance to deterioration with age than rubber made in the usual ways, according to J. W. Schade of the B. F. Goodrich Co. and it can be made at lower cost.—*Machinery*, July, 1927, vol. 33, no. 11, p. 828.

[5] Asst. Gen. Supt., Washburn-Crosby Co., Minneapolis, Minn.

Railway Apprenticeship in a National Apprenticeship Plan

Present-Day Rigorous Requirements of Railway Mechanics—The Santa Fe's Apprentice System—School Work Supplementing Shop Instruction—Outside Apprentice Activities—Results

By F. W. THOMAS,[1] TOPEKA, KAN.

THE present modern apprenticeship is scarcely sufficiently in vogue upon our railroads to profitably discuss it as a national or universal system. True, we have a national system of accounting as prescribed by the Interstate Commerce Commission. We have a national system of car interchange regulating the construction and maintenance of freight and passenger cars, which makes it possible for cars of one road to be handled upon another road along with the latter's own cars. We have a national scheme of safety appliances promulgated by the Interstate Commerce Commission to which all roads must subscribe. We have a national scheme of rates, freight and passenger, prescribed by the Interstate Commerce Commission, which all roads in a given region, large and small, rich or poor, must recognize. But important as the matters may be, they nevertheless deal with objects, not with men.

Just as there are no two human beings alike, so are there no two managers who manage alike. There would be but little difficulty in promulgating a scheme for training apprentices which should be applicable to all the railroads in the country; the rub comes when an attempt is made to apply the scheme, each manager deeming his methods the better. So we shall only attempt to discuss a scheme or system, to outline one which should embrace certain cardinal principles to make it operative and successful. The old scheme of binding out a boy to a master has gone, and no one now would revive it; education is too general, too selective, for such a method. Keep and board are not the right kind of remuneration, and one's ideas of freedom and liberty revolt at this method.

Requirements of Railroad Mechanics More Rigid

The second stage of indenturing a boy to learn a trade with pay and placing him in your shop to "root, hog, or die" under the prevailing demands for output, without any one to guide or direct his young hands, results too often in not the survival of the fittest but of the toughest, and few, very few, American boys will stand such rigorous treatment. So if we are to have an apprentice scheme fitted to our needs, it must also be fitted to the times and to the boy of the day. We must teach him his trade with modern methods surrounded by modern equipment. In the commercial or manufacturing field there is not such a demand or requirement for the so-called all-around, skilled mechanic as with the railroads. A worker in a large manufacturing shop will perform one job hour after hour, day after day, year after year, and become an automaton or a machine. He can be taught to do that job in a few hours, improving with practice and time, but he is good for only that one job or operation, while with the railroads he may be called upon to operate the simplest sort of lathe in the morning and the most intricate universal miller in the afternoon. He may be assigned to the erecting floor the next morning and to the roundhouse for running repair work a few hours later. The requirements of a railroad mechanic are greater today than ever before, and the introduction of new complicated machines, some automatic and semi-automatic, has not lessened the skilfulness of the operator, certainly not in our railroad shops.

The intervention of Federal and state governments in the operation of the railroads has so flanked the latter with rules and laws as to the repairs and maintenance of equipment that the present-day railroad mechanic must be a mechanical lawyer as well as an artisan. There are over 50 laws or rules governing the maintenance of locomotive boilers. There are over 50 laws or rules governing the maintenance of the machinery for locomotives. There are several hundred rules governing the maintenance of freight cars. When and where must he learn all these rules and laws? He can't wait until his road is haled before a court for some act of omission on his part, nor can he afford to have his road's equipment tied up with a yellow flag by a Federal inspector. He hasn't the time to stop work and look up the law or rulings on the height of a car coupler or the crosshead lateral allowable by the inspectors. He must have these on his tongue's end, ready to answer and apply.

The Sante Fe's Apprentice System of Training Mechanics

How are we to secure such men, such artisans, such mechanical artists? I am speaking only for the road with which I am connected and which I serve. We have now and have had for twenty years a real apprentice system of training and educating mechanics for our shops, enginehouses, and car yards. It starts with the selection of promising boys, and through a well-defined scheme of shop and schoolroom instruction fits them for any class of work of their chosen trade. The educational requirements of applicants are not exacting, in fact, very reasonable; any eighth-grade boy should meet it. A little practical psychology in examining the applicant will generally forecast his future. We care nothing about character letters; do not ask for them, and often fail to use them if offered or received. We do care for the boy himself, his mental activity, his industry, his interest manifested in the trade he wishes to learn. His indenture requires him to learn, and obligates the company to endeavor to teach him the trade. To carry out this obligation we do give him an opportunity, the best we can provide, and it may be said that the Santa Fe is very resourceful. All the brains, the talent, the experience, the machinery, and devices of that great railroad are back of that obligation, and the management will accept no excuse, no explanation for the failure of the party responsible to give that green boy a full, complete opportunity. To carry out this obligation we have organized and developed the necessary machinery. The boy, after indenturing himself, with the approval of his parents, is placed in the shops where he starts out on the four-year course. We have provided shop instructors, the best men of the line, to take him in hand and teach him each and every branch of his trade, the operation of the various machines, the performance of the various vise and bench jobs, the various jobs on the erecting floor. He is taught the best possible way of performing each job; to take care of his person; to avoid injury to himself or to his fellow workmen; to preserve and save company property and material. He is taught promptness and regularity in his work and obedience to authorities. He is shown and taught the correct interpretation of the various Federal, state, or company rules respecting the work in hand through practical contact with the object. A set schedule is prepared for each shop, and all are given equal opportunity.

School Work Supplementing Shop Instruction

Supplementing the practical shop instruction, apprentice schools are maintained on shop premises where the apprentice is required to attend two sessions per week of two hours each. He is taught mechanical drawing. (One of the best training subjects for a mechanic, as it teaches him to be exact—I have no faith in these so-called "blueprint reading" schemes.) He is taught free-hand drawing or sketching to enable him to readily illustrate his object; some shop mathematics—arithmetic, algebra, and geometry, all grouped together and called "problems;" a treatise on his trade; the company book of standard practices, the theory of special

[1] Supervisor of Apprentices, Atchison, Topeka & Santa Fe Ry. Co.

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subjects or elements, air brakes, superheaters, boosters, valve setting, company, Federal or state rules, and laws relating to work in his department; and finally given an examination on the subjects we have been teaching him all these four years as a test of his memory, industry, and application. A schedule time is set for each drawing, each problem, and each supplementary subject; for example, we allow him 3.2 hours for making Drawing 47, 40 minutes for working a block of five problems, and so on through all the subjects. This gives us a good idea of his industry, aptitude, and application.

The schedule is made to fit the average boy and must be complied with if the apprentice is to be graduated. Many forge ahead of the schedule and are given supplementary work which increases their general knowledge and places them on the honor roll of "possibilities for promotion." We have established one thing in handling apprentices which has proved most valuable in ascertaining the fitness of the apprentice to continue his apprenticeship: a probationary period, the first six months. During that period he must show unmistakable evidence of talent. Second, we created a reviewing body known as the Apprentice Board, composed of the master mechanic, general foreman, department foreman, and shop and school instructors. This board meets once a month and discusses all apprentices in the probationary period and all others once every six months, or oftener when their names are brought before it. It endeavors to find out everything pertaining to the individual apprentice; encourages, corrects, disciplines, or dismisses as occasion demands; devises means for bringing out the timid or backward boy; endeavors to strengthen the weak though willing boy; encourages the strong, the active, and the promising. The members of the board are inquisitive, fair, and impartial. They know the boy as a man will soon be working for them, and all foremen are anxious to have good men. We encourage and aid these young employees not only in developing into good mechanics, but in becoming loyal employees, good citizens of the community.

Outside Apprentice Activities

At each mechanical point the apprentices are organized into clubs which handle all their outside activities. These clubs offer opportunities for athletics in season, social diversion, and education and cultural diversion. They have glee clubs, bands, orchestras, etc., base-ball, foot-ball, basket-ball teams, often tournaments bringing teams 1000 miles for the contests. These apprentice clubs have an annual conference limited to four delegates from each club, but in addition each club may send a basket-ball team. These conferences are gala events, much sought by cities along the line from Illinois to California, and much prized by delegates. To be eligible for club membership or as a member of an athletic team, each must be up in his scheduled apprentice work and enjoy the endorsement of his apprentice board. Cups, trophies, and prizes other than money are offered. One formal party or dance is given by each club yearly, with informal parties or picnics more frequently in season. The whole scheme is to make first-class mechanics, superior to any in the world; intelligent and valuable citizens for the community; contented, happy, and loyal employees for the road.

You may say this costs money. All good things cost money, but one railroad has found that it is a paying investment. There is no road in the country that has mechanics superior to those on the Santa Fe; there is no road that has a smaller labor turnover. We have shops on our line which have not employed a single mechanic from the outside for eighteen months. Very probably none will be employed during this entire year.

Results

While our chief purpose is to provide first-class skilled mechanics to man our shops, we enjoy other blessings from our apprenticeship system. It furnishes ample material for all our shop foremen, draftsmen, for our designing or drawing rooms, assistants for the test department, staff officers, inspectors. Is it not worth something to the foreman, to the master mechanic, to the management to know they have men in the ranks, trained and drilled for any emergency—for any vacancy—for any position? The apprentice system during the past fifteen years has furnished the Santa Fe from its graduates: 7 master mechanics, 23 general foremen, 16 roundhouse foremen, 63 assistant roundhouse foremen, 39 machine and erecting foremen, 18 boiler foremen, 47 apprentice instructors, and 29 other positions above the ranks or a total of 242 in official or staff positions. These are young men with long years of usefulness ahead of them, years to serve the road which has trained them. The human element has been greatly neglected by many of you. It has been, is now, and always will be your greatest problem.

Discussion

ORAL discussion was opened by Chairman Magruder with the expression of a hope that a national plan would grow out of the Sante Fe program. On a question by S. I. Flournoy,[2] John H. Linn[3] explained that the scheme was by no means a theory but had been tried out for almost twenty years on the Sante Fe and that graduates of the system had installed it in other roads such as The Duluth & Iron Range, The Duluth, Missabe & Northern, The Missouri, Kansas & Texas, and the Kansas City Southern. He said that the age limit for regular apprentices was eighteen to twenty-two and in the car department eighteen to twenty-six. The regular apprentices were paid at the rate of 33 cents an hour at the start, with an increase of two and a half cents per hour each six months for the first three years and slightly larger increases for the fourth year, the rate for the eighth six-month period being 58 cents per hour. The rate for the freight carman apprentices was somewhat higher namely 48 cents for the first period and 63 cents for the sixth period.

T. C. Gray[4] said that he had the advantage of four years' apprenticeship under Mr. Thomas ten years ago and would not trade it for his college training although he prized that very highly. He expressed the opinion that this training was the foundation for his success and declared that Mr. Thomas deserved great credit not only for training valuable mechanics but also for training good American citizens.

Mr. Thomas added to the discussion by referring to the second paragraph of his paper, explaining that there could be no National apprenticeship scheme so long as there was such a divergence in the opinions of managers. He asserted that the whole scheme of education in this country was based on many opposing views and cited instances of the difference in the curriculum of the public schools in different parts of the country, and said, "in colleges I believe sometimes that professors and learned men are in competition to work out the hardest and most unintelligible text books applying to mechanical engineering." He stated it as his belief that two-thirds or three-fourths of the things done on railroads could be standardized, such as mathematics, federal rules, etc., and that if some such organization as the American Railway Association could secure this standardization the result would be a tremendous and wide-spread benefit. He called attention to the fact that with a mania for vocational guidance and education in the schools, the trades could not get enough apprentices. He blamed this on a lack of effort to make the apprenticeship attractive and such as would assure the apprentice of being taught a trade. He suggested that the building trades, plumbers, etc., would follow the railroad's lead in this respect only when the general public insisted on competent workmanship in the trades.

Floyd L. Weakly,[5] after explaining that he served an apprenticeship and had valued it highly since, because of it, he could show a workman just how to do the work, said that he understood that present-day requirements would not allow the ex-university man, as formerly to have the privilege of apprentice training unless he intended to stay and give his time to the railroad. He asked what opportunity there was in the shops now for a college man.

Mr. Linn answered this question by stating that on the Sante Fe railroad a three-year special apprenticeship course was open to graduates in mechanical engineering. This included a year's train-

[2] W. S. Dickey, Clay Manufacturing Co., Kansas City, Mo. Assoc. A.S.M.E.

[3] Atchison, Topeka & Santa Fe Ry. Co., Topeka, Kan.

[4] Supervisor of Apprentices, Missouri, Kansas & Texas R.R., Parsons, Kan.

[5] Consulting Engineer, Kansas City, Mo.

ing in general machine work; a year on erecting work; and a third year consisting of four months in the round house, two months each in the boiler shop, car shop, with the traveling engine, and on special work. The third year, he said was open to a limited number of regular apprentices. No promise was made to the men but the purpose of the course was to recruit young men for official positions. The pay started at 53 cents an hour with an increase of two and a half cents every six months, followed by mechanics' pay on completing the course. These graduates held seniority, as mechanics as did regular apprentice graduates at the beginning of the second six months of their apprenticeship.

Mr. Gray told of the first year's experience of the Missouri, Kansas & Texas with its special apprenticeship plan. The technical graduates numbered but three and were required to be not only mechanical engineers but graduates and specialists in railway mechanical engineering. He expressed great gratification with the results and said that the men were the equal of their best regular apprentices and not afraid of hard or dirty work. He said the routine varied but slightly from that expressed by Mr. Linn, mainly by giving them some time in the electrical department instead of with the road foreman and by sending them out with the air instruction car to get experience in train handling. They were also required to submit a monthly report of around 4000 words on different subjects such as track stresses, locomotive design, etc., thus keeping brushed up on their school work during the course.

In response to a question by H. K. Browning[6] as to what use was made of educational features furnished by the coöperation of manufacturers, Mr. Linn explained that the railroads received a great deal of such coöperation through films, lectures, etc. Such special instruction was frequently carried out through the apprentice clubs that took care of athletics, etc. He also said that the railroad had sent some of its apprentices to the Baldwin Locomotive Works, The Pullman Co., and The Westinghouse Air Brake Co., and others. Mr. Browning mentioned past coöperation of his company in this line and expressed his willingness to coöperate in the future.

J. S. Y. Fralich[7] explained that in 1900 he served an apprenticeship of three years at sixty hours a week at only 5 cents an hour. He said that, although he did not regret the time spent, as he would have had a hard time determining whether the apprenticeship or his college training were the more valuable to him, still he did not get much money. He felt that one of the difficulties in getting apprentices was the fact that many companies did not pay enough. He gave it as his opinion that the average college boy was afraid of hard work, especially dirty work. In the Westinghouse Air Brake Company one of the tests was to give the apprentices a dirty, nasty job and, as he said, "it is surprising the percentage that will not stick." He emphasized the importance of teaching the students that they must do the dirty work before they get the clean work. He said that his company was taking some fifteen or twenty mechanical and electrical engineering graduates for a six months' course that was practically probationary, during which it could be determined whether the company liked the men and the men liked the company. These men were paid sixty cents an hour during this period and were then assigned to work according to their ability. If at the end of this period one of the men could handle a four- or five-hundred-dollar job there was a good chance of his getting it; but few had measured up to this scale.

He also called attention to the lack of apparatus in many engineering schools and the need for instilling a little more of the practical side of the job through this apparatus. He felt that the average graduates had all the necessary theory but not enough practice.

Mr. Linn pointed out that the apprentice should receive much more than his wages, that the experience given the apprentice was an important element in his pay, that most of the roads did not give the apprentice the training and experience he had the right to expect. He said that his railroad never had trouble getting boys for apprentices but had a waiting list sufficient for a year or two. This he felt was because the railroad gave the boys plenty of experience and promotion, trips, club activities, and athletics. He said that recently there had been a tournament of fifteen basketball teams made up of apprentices, many being former college stars.

He quoted Herbert Hoover in speaking of the railroads as saying, "We have devoted ourselves for years to the intensive use of machinery and improvements in the processes of production and we have neglected the broader human developments and satisfaction of life of employees that lead to creative interest and coöperation in production. It is by the stimulation of these factors that industry will be lifted and placed upon the plane of development reached by our mechanical processes."

Mr. Thomas was then called upon to close the discussion. He said that the Sante Fe thought so much of the system that, even where there were only four or five apprentices at a point, traveling instructors visited them as frequently as was necessary and that Mr. Ripley, the former president who approved and adopted the system, would not allow them to quote the cost of training as he said that the value of a well-trained human hand, heart, or eye could not be measured in dollars. The boys at the smaller points, Mr. Thomas said, were moved to larger points to round out their training, and the very best apprentices came from the smaller points, in spite of the disadvantage of lack of full equipment.

He referred back to the last paragraph of his paper and said that practically all the help the Sante Fe needed in the engineering department was recruited from the apprentice system, including the draftsmen and assistants to staff officers, and that in the last fifteen years it had been unnecessary to go outside to employ a single mechanic. Recently seventy-five men were provided from the system to do some special valuation work on the railroad.

He pointed out that the railroad, which was well managed and required an accounting for every penny, thought the system was worth while and had given liberally of sufficient means, money, and talent to make it the best system the officials could devise. It was not tied to tradition. All instruction sheets were loose leaf and kept up to date to fit all modifications in equipment, etc. If necessary the books could be revised every month.

Chairman Magruder, in bringing the discussion to an end, pointed out that Mr. Thomas had brought out the human element as represented by Mr. Ripley and that if Mr. Ripley had not loved human beings the Santa Fe would not be where it was today. He said that some railroads paid only 75 per cent of what the Santa Fe did, hounded the apprentices, and gave them no instruction. He suggested the absurdity of trying to pay 80 per cent of what many roads paid and throwing out the mediocre men at the end of three years.

He spoke of how one of the largest railroads in the country set an apprentice to tacking down sheets of galvanized steel on the wooden floor of the machine shop, apparently because he had nothing else to do, and in spite of the likelihood of accident from tripping, only to discover two months later that the boy had knowledge of geometry and trigonometry and could then be used as a machinist's helper in laying out difficult castings and forgings.

He condemned the requirements of certain railroads that all persons seeking employment must report to a central point and emphasized the small chance of a boy's going to that trouble and expense unless he had an exceptional desire to enter the employ of that particular railroad. Times had changed, he said, and railroads were beginning to realize, as the motor-car people had found out, that a good commercial salesman did not necessarily make a good engineer, and they were asking for more high-school and college graduates to train as machinists and technical apprentices.

He pointed out the practical impossibility of fulfilling a union demand that no special apprentice be put on the road unless he had served his time or had begun to serve his time after graduation and before he was twenty-one, because most college students were over twenty-one when they were graduated. The railroads, he said, must solve that problem and must train executives for the higher positions and have them know the ropes from the bottom all the way up.

He expressed the opinion that the graduates of the best colleges were better trained than formerly and did not have to be introduced to dirt, as they were required to be out in industry so as to become acquainted with the needs of industrial employment before their senior year. In closing he emphasized the effect of variation in wages as given by different roads and said that the natural result was for the young man to seek the road that paid him best.

[6] A. M. Byers Pipe Co., Pittsburgh, Pa.

[7] District Engineer, Westinghouse Air Brake Co., Chicago, Ill. Mem. A.S.M.E.

Education for the Industries

Specialized Requirements That Must Be Met—Need for General Education of Public as to Economic Basis of Industry, More Complete and Thorough Job Training, and Education for Industrial Leadership

By P. F. Walker,[1] Lawrence, Kan.

The economic situation of this country has changed in many respects during the last few years, bringing into prominence several factors which were secondary in the preceding period. The nation emerged from the World War with a new vision of industry in relation to world markets, but with conflicting conditions to be adjusted. Man power is one of those conditions. We are concerned with both quantity and quality of that factor in the mass. We are even more concerned with leadership—the directive force that must guide the mass in its work.

The widening market for manufactured goods is not the only element that is bringing a change of emphasis. There is an actual falling off in exports of basic raw materials. Those products gave us a favorable balance of trade for many years, but the situation is changing. The exportation of wheat is diminishing. In a few years more it will cease to be a controlling item in world commerce for this country. Our forests are disappearing and the time is at hand when the utilization of timber resources must be adjusted to the rate of accretion by natural growth. Already the importation of pulp wood and pulp from Canada has become necessary. Carefully made studies are revealing the fact that the next few decades will witness the end of significant exports of coal and oil, as well as of various other mineral products in raw form. We are now importing many commodities in this class. The center of gravity of our export trade is shifting definitely toward manufactured products.

It is likewise a fact that within the continental United States there are no longer extensive areas of tillable land waiting to be occupied, or unexploited forest and mineral resources to be developed. Those avenues by which our expanding population provided for itself during a century and a half of growth are being closed. We face a program of intensive development rather than extensive. In the future we must draw upon human resources rather than on the material natural resources of an intrinsically wealthy nation. This means that the education of our people in the economics of a new epoch of progress is necessary. Changes are gradual, but this fact, while it is a fortunate one, is itself a source of danger by reason of its tendency to becloud the issue and so lull us into an attitude of repose and contentment with present conditions. Action is imperative.

The direct issue confronting us in this developing phase of commercial activity is competition in the world market. Competition is not a new element, to be sure. Our wheat exports have dwindled because of the competition from growers in the Argentine and certain other countries where the producing areas are near the seaboard so that the grain moves but a short distance to seaports for movement to the principal markets, while our crop must be carried long distances by rail to reach the sea carriers. That competition is winning out, because there is no effective method of overcoming the handicap. But in the form in which this problem appears to our producing industries it is a thing that must and can be met. Future commercial activity and national growth demand that the issue be met.

To do this we must achieve economical production, and to produce at low cost with a high wage scale is an achievement of no small magnitude. Our standards of living are high, and no one desires them to be otherwise. It is a tradition that has become a settled fact—an element in our civilization. But to accomplish the necessary result of low production cost will require all of the ingenuity and energy of which our industrial administrators are capable.

The trend of industrial procedure has been favorable to this end. As compared with European countries we have had the combination of high wages and cheap fuel, against their combination of low wages and costly fuel. As a result we have conserved labor at the expense of power. Equipment and labor-saving appliances are characteristics of our system. We have gone far in developing the machinery of production in physical forms, until it may be said that we are nearing the point where the law of diminishing returns becomes operative. Automatic and semi-automatic machines have been perfected to the nth degree to meet the exigencies of mass production. The limit has not been reached, and activity will continue in this line, but other considerations are coming into relative prominence. A direct result of the extended utilization of such equipment has been large investments in plant, capital for which has been plentiful in America. Our industrial system is thus characterized by the extensive use of capital, large power consumption, and a minimum of labor.

While this development was going on during the half-century following the Civil War, under the fostering influence of a protective tariff designed to promote manufacturing for the domestic market, there was no pronounced need for economy in the use of material. It was only as living costs forced up the wage scale that labor economy became necessary. Even so, the labor cost per unit of product went to high levels, and it was this fact that brought the attention of executives to the need of stimulating output per worker. The accomplishments of Taylor and the others who took up the work with him have demonstrated the significance of the human element. The past twenty years have marked the beginning of a new epoch, in which attention has turned largely toward personnel. The results attained indicate the possibilities that may be realized as we proceed under the changed economic conditions. They point the way to the ultimate solution of the problem of economical production in the coming period of industrial competition in the world market.

But as a matter of fact this present epoch in industry is one calling for scientific treatment of more than the labor factor alone. Every element in production calls for scientific treatment. It is the age of science. Not in production only, but in materials, in marketing, in transportation, and in general financial administration, there lies the opportunity for effective employment of the scientific method of attack in the solution of the problems which arise. The new conditions must be faced frankly. The day has passed when the owning of corporation stock in the enterprise was the passport to a managerial berth and salary. Controlling the forces of production has become the work of the trained expert. It is a matter of education.

One other element growing out of the past remains to be noted. The half-century following the Civil War, which constituted what we may term the "equipment era" in industrial development, coincided in time with the inauguration and growth of our engineering and polytechnical schools. Those schools, and especially the mechanical-engineering branches, became impregnated with the same infusions which were dominating the practitioners and giving form to industry in its formative years. Technique in machine designing and in power generation became the basis of the curriculum. Therein lies the crux of the educational problem for industry of today, as respects the higher formalized forms.

The New Demand

As we turn to the future there appear various types of specialized requirements that must be met to realize the possibilities in the new order. Some are already formulated in established practices;

[1] Dean, School of Engineering, University of Kansas, Lawrence, Kan. Mem. A.S.M.E.

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others await the attention that will come as present economic tendencies develop the need.

Reference has been made to the producing capacity of the worker. The high earning power as determined by a wage scale adjusted to living conditions must be matched by output in order to hold unit costs to a competing level. The history of progress may be expressed in terms of the worker's productive power. Utilization of mechanical power and refined equipment has contributed to this end. The present era is one in which the advance comes by the more effective expenditure of human effort, not by driving the individual but by coördination of the many human elements which enter into the processes of management and operation.

In a nation abundantly supplied with the wealth of natural resources, capital should carry more of the burden and labor less. Equipment should be worked harder and more continuously while men are enabled to contribute their part through intelligently directed effort, with comfort and advantage to themselves. The trend toward shorter working hours for labor does not imply, necessarily, a similar shortening of the hours of employment of the plant with consequent addition to the overhead of investment charges on output. This is one of management's responsibilities.

The waste of time and effort represented by friction, unrest, rapid labor turnover, and misfits in the industrial machine must be reduced. It is the human-relations problem that is present wherever people are gathered in masses for any common enterprise. There is need for the same attention to this as to any of the problems of material and equipment—greater need than for any others, many will say. It represents the function of leadership, than which there is none greater.

Processing in manufacture calls for scientific development in increasing degree. Certain industries demand chemical technologists. More and more the coal and oil derivatives are assuming place in our program, and in many other fields a more exacting adjustment of materials to requirements and the development of new compounds call for the employment of the chemist. The petroleum production companies are establishing research divisions manned by geologists, physicists, and engineers of high qualification. The research activities of the large manufacturers of electrical and metallurgical products are well known for their completeness and variety of program. The need for trained technologists of all kinds is being felt in many industrial establishments which have not employed them in the past.

The sales organizations of the large industries are calling more and more for technical men. Builders of equipment, especially in the machinery lines, are giving more attention to service rendered their patrons. This type of demand is so well recognized that it need be only mentioned here.

The public-service organizations of the country are assuming a position of ever-increasing significance. Electricity, gas, and communications services are in the class of "big business," permanent in their establishments, and are absorbing in their organizations large numbers of engineers and other men educated in business and commercial branches.

Banking and other financial houses are calling more and more upon technical consultants for examinations and reports on industrial establishments. It is a movement in the direction of stabilization of investments and the placing of the manufacturing business of the country on a firmer and more permanent basis.

These and still other developments in the structure of American business are giving form and direction to the training of the personnel required for the consistent upbuilding of our industrial life. Men of specific qualifications are in demand. How far these qualifications may be developed in the formalized educational institutions, and to what extent the business establishments themselves must assume the task of training, remain to be considered. The obvious fact coming more and more into evidence is that personnel is the outstanding element in our national industrial system. The material and equipment factors are reasonably well established. The need is for men.

The Educational Program

There are several distinct types of educational training required in fulfilment of the demands which have been outlined. They may be defined under the following general heads.

First, there is a need for general education among the masses. This refers to the general public as well as to people actually engaged in industrial pursuits. There is need for a better understanding of the general industrial policy of the country, and of the economic basis of industry. It should be provided for in the public schools, for which new text material is necessary, in addition to the books on elements of general economics and commercial geography. It should give, in simple form, the basic industrial principles and methods, and some adequate idea of the cost elements of manufacturing.

For groups of employees in the industries themselves it may take the form of detailed information regarding business conditions in their special industry, market variations, processing costs, new developments, and the ways in which their own factory products fit into the needs of modern society. Many workers now have but scanty idea of, or regard for, the public-service features of the enterprises of which they form a part. They have no incentive to effort coming from a vision of human needs supplied or service rendered. Production for them has come to mean nothing more than conforming to cold, inanimate standards measured by the inspector's gage. How far this thought may be carried depends upon circumstances and the nature of the product, but attention is being given to it in many plants. Meetings for discussion, either in mass or by representatives in shop committees, are the agencies for disseminating such ideas.

A more tangible procedure is the establishment of part-time schools for younger employees and newcomers of more mature years. In such schools there may be united the two objectives of general education and job training. In some instances they are adaptations of the continuation schools required by law in some sections of the country for youthful workers. Their importance in the development of a more intelligent body of employees is evident. More should be done in this direction.

Secondly, there is need for more complete and thorough job training. This includes the general problem of apprentice instruction, a phase of our industrial life which is undergoing change at the present time. The maintenance of the working forces of our industrial establishments is at stake, which means that adequate consideration of the problem is demanded. One branch of industry, railroads, is represented by a separate discussion at this meeting. The general plan that may be adopted should be predicated upon a careful job analysis, carried out for a wide range of services. Some of our active and progressive companies are giving much attention to the subject. It is out of the range of this paper, and it will be dismissed with this passing reference.

The third vital need is for foreman training. This topic again is one to which attention is being given in a separate paper at this time. Needless to say, it touches the vital spot in our industrial system, namely, the problem of leadership. There is no more vital principle in the whole scheme of industrial training. The effectiveness of the shop-committee system, and the means for carrying to the mass of workers correct information respecting the progress of the business and the aims and policies of the higher administration, depend on the type and efficiency of these foremen. In a very real way foreman training is essential to the future development of industrial enterprise in this country.

Finally, the need of industry for men of definite qualifications carries us into the field of formal education. In many quarters the call has been sounded for leaders—men who are equipped by temperament and training to direct and stimulate the work of others. It is not alone the leadership of groups in which there is felt the influence of personal contact, but it extends to the larger directive functions of industry in its social and economic phases.

In a recent address, Magnus W. Alexander, president of the National Industrial Conference Board, divides this field into three parts. In the first this function of leadership is the paramount issue. Individuals who thus serve exercise managerial responsibility. Their contacts are with the affairs of business and commerce. It has special reference to conditions where the nature of the enterprise is such that a measure of technical training, based on the underlying principles of applied science, is a necessary element in the preparation of these men for their tasks.

The second group is hardly distinguishable from the first. It

is made up of highly developed engineers and chemical specialists, broadly trained in scientific fundamentals and experienced in accordance with the highest professional standards. They represent the best type of professional technologist, who has brought industrial equipment to its high level of excellence and developed processes that have contributed to the industrial achievements of the present day. They are the product of our best schools of applied science.

As suggested, there is no clear dividing line between these first two groups. When industry called for the shifting of emphasis from equipment to the human element, many men of the second group, highly developed engineers, keenly alive to the economic necessities of the time and interested in attaining the highest degree of effectiveness, took up instinctively the role of industrial executives. They carried with them the scientific method and the investigative spirit. They have done much to carry forward the program of industrial advancement. By reason of the successes attained by many of these technologists who become managers and directors there has been developed in the minds of industrial owners the desire to utilize men of scientific training for administrative function. Possibly they have gone too far in this direction and have found that all of the men trained in engineering are not adaptable to transfer into the directive field. As a result of this experience there comes the call, and it is one to which a deaf ear may not be turned, for modification of the training process which has developed these men of high technical qualifications in order that they may be adapted to transfer into the field of administration. This call is epitomized by Sam A. Lewisohn in his recent book The New Leadership in Industry. This is an interesting and valuable discussion of the opportunities of industry, and of the part which men of basic engineering training may take.

The third division in Mr. Alexander's classification is that in which the service requirement is of a routine nature, although based on a type of training best secured through educative processes of collegiate grade. The higher type of draftsmen, men who are capable of carrying out the ordinary routine of design, investigators of operating technique, construction engineers, and technical chemists represent this field. When viewed from the standpoint of education the question arises at once, shall men for this work be recruited from the ranks of those who have aspired to the field of higher technology but whose personal qualifications are such that they have dropped back into the routine of every-day service, or should there be developed a special type of educational institution, with curricula adjusted to this end? Shall such branches be established alongside of the other in the existing colleges of technology, in which will be trained the men who look forward to this work as a direct objective?

The searching out of the plan which will best realize the needs represented by this three-fold requirement has been occupying the attention of engineering educators and many engineers and leaders of industry during recent years. An extended investigation is now in progress, with which many members of this organization are familiar. This study has caused many institutions to review and formulate their objectives with a more zealous regard for the requirements of industry into which their graduates pass. One of the prominent eastern schools, one which has had a long and honorable career, has recently formulated its policy in these words: "The engineering curricula in this institution shall give fundamental training in pure and applied sciences, in economics and the humanities, for a professional career, and the institution shall emphasize the importance of the service which an engineer may render to society. This institution is not interested in preparing men who are primarily technicians and who will follow engineering as a vocation."

This is a frank statement which places this institution in the direct line of meeting primarily the second division, that of highly professionalized technical service, but giving at the same time a recognition of need for the professional man who moves into the field of executive and administrative duties which characterize the first division in Mr. Alexander's classification. This school proposes, therefore, to provide men for these first two fields of scientific service, probably with its initial stress on the second, which is the more highly professionalized engineering service.

In this recent pronouncement this institution is merely expressing in definite words a policy which has characterized its activities for years. The same thing can be said regarding a score of institutions in different parts of the country, where the major effort has been directed along the lines thus formulated. Unfortunately, there are many institutions in this country which are endeavoring to train men for these higher fields of professional and administrative activity, but which might more properly and efficiently give their attention to the development of men to enter the third field. It may surprise some to know that the recent investigation referred to has recognized about 150 institutions which give degrees in engineering. It is not clear that any appreciable number of these are giving their attention to the meeting of the call for the third division. There are a few institutions, usually not presuming to give full professional degrees, which are doing excellent and most valuable work in this direction, but the number is in no wise adequate to meet the need.

It is my opinion that this is the most difficult point to be met by the engineering schools in their efforts to adjust themselves to the needs of industry. Those who have been giving direction to the course of this investigation have stressed again and again the importance of this need for men of shorter training. It is one item among the various specific recommendations submitted to the individual schools. But it is the one to which it is most difficult to give a specific response. Those institutions committed to professional training foresee a real difficulty in attempting to train a second class of students in a less advanced field. To permit this second school division to become merely the city of refuge for those who fail to realize their higher ambitions does not represent a healthful situation. Of their own volition, a disproportionately small number will go to the institution of high rank, and follow therein a curriculum of lesser merit. If the spirit animating them and their parents who send them, leads them to the institution of high rank, the ambition and pride which is theirs urges them to attempt the higher goal.

The only solution is that of selection on the basis of ability and the assignment of individuals to that institution for which their abilities fit them. This is a remark easily made and readily enough accepted in principle, so long as our own boys are not the ones assigned to the lower type of training. The simple fact is, however, that we have not yet reached the point where individuals are ready to commit themselves to the guidance of such a distinctly selective process as this represents. Publicly supported institutions in particular are helpless in the face of this fact. We may advise and urge, but only the actual results of an attempt to master the higher demands will convince the individual of his lack of fitness, and pride frequently drives him on in a barely passing status, always aspiring but never attaining the objective. The result is that the secondary curriculum becomes merely the resting place of those who have failed. As such, it can never engender the enthusiastic spirit that comes with accomplishment in a chosen field.

With a segregated institution the situation is much better. A shortened curriculum with a less expensive scheme of education places this separate institution within the reach of many whose financial circumstances permit them to consider only a shorter period of training. There should be coördination between this institution and the highly scientific institutions in its neighborhood. Men of unusual ability may be brought to the forefront and passed on to the higher institution in case their financial condition permits. In the system of state-supported institutions this principle should be recognized. It is reiterated, however, because of the tendency to overlook the point that this field of service is not met by the vocational schools of secondary grade. This group of men should be conducted along an educational plan that is based on a collegiate-grade training in mathematics and physical science, not necessarily carried to the higher levels as in the professional school, but distinctly of collegiate grade as far as it goes. They should include the basis of a liberal training, limited only by the time element. On such a basis the student who discovers his latent powers, and finds it possible to give more time and money to his educational training, may go on without material loss of collegiate-grade credit which has been earned.

There is difference of opinion on this question of the necessary segregation of the work represented in this third type of training.

It may be that the way will be found in the not distant future whereby a properly recognized and dignified division within the single school may be made possible. Selective tests to determine ability may become so well established that individuals will accept results and proceed with satisfaction and cheerfulness to fit themselves for those types of industry to which their qualifications fit them. It is a result to be devoutly hoped for.

There is much more that should be said regarding the adaptation of the standard professional engineering curriculum to meet the needs of industry for the administrative type of professional service. A question which arises here is whether it is best to indicate certain curricula to be followed by those who aspire to the field of administration, or whether the entire professional group should have their study directed along lines which give attention to the broader field of social and economic enterprise. If the first method is advocated, there arises again the question of selection. Many of those who aspire to the field of administration may be unfit, while the finest prospects for that service may have ingrained tendencies which lead them into the more highly technical work. As in many other instances in life, it is probable that a compromise is necessary. I am disposed to stand with Mr. Lewisohn in the belief that all engineers should be given a measure of training in lines which will direct their attention to the opportunities in the administrative field.

Discussion

C. M. MILLER,[2] discussing the paper by Dean Walker, stressed the importance of a closer relationship between education and industry. Since the industries supported education liberally, he said, it behooved education to return the only form of dividend possible—individuals well trained for the specific duties they might be called upon to perform.

Technical engineering ability and executive or administrative engineering ability impressed him as separate commodities in the industrial field, and rarely developed to the highest degree in the same individual. Although a business executive in charge of engineering was the better for an engineering background, he questioned if the two qualities could be developed equally by giving a group the same collegiate training. The third group to be given careful consideration was that of the actual workers who put the plans of engineer and executive into operation.

Although we had not developed a method of accurately measuring a man's intellect, he felt that we could determine roughly, at least whether a man might be reasonably expected to succeed in engineering. In his view, we did a man a favor when, by reliable test, we determined that he was not fitted to enter a given activity, provided we gave him the best possible training in the line to which he was adapted. In his opinion democracy was not justified in expending all its educational efforts on leadership, as only a small percentage could realize great achievements.

He opposed a long training period in institutions for the mechanical worker, preferring that the training be given largely on the job. This was best, he thought, because otherwise newly discovered principles might require that the worker relearn his trade. He closed with the declaration that, to serve industry, education must consider the training of leaders and workers as equally important. He thought one of the best methods of reaching the worker was through the foreman.

L. A. Hartley[3] gave his appreciation for Dean Walker's paper and expressed the opinion that his committee would be willing to endorse it.

F. W. Thomas[4] expressed his appreciation for Dean Walker and his paper and said that the people of Kansas felt that the money spent by the state for education should provide training for the industries of the state. He thought that to do otherwise was one of the mistakes that the schools made and that the schools around Pittsburgh should train men for the steel industry. He emphasized the importance of greater individual attention in education to bring out the respective talents of the students.

[2] Director of Vocational Education, Topeka, Kan.

[3] Director of Education, National Founders Association, Chicago, Ill.

[4] Supervisor of Apprentices, Atchison, Topeka & Santa Fe Ry Co., Topeka, Kan.

Chairman Magruder expressed the feeling that the engineering schools were not doing their duty. He enumerated four classes needing training. First came the trained specialists who should have four years of training and two or three years of post-graduate work and should become special research men to solve problems and do analytical work, such as the General Electric and other companies were requiring. Second were professional engineers, third, the foremen, and last tradesmen, sales engineers, and others who frequently did not need full engineering training.

He spoke of the enormous percentage—sixty-eight per cent in his own department—of engineering students who did not receive degrees; and expressed the opinion that the schools should try to provide a different kind of training for each of the four classes. In this way, he thought, the students would be classified according to their capacity and many would be put into industry much quicker than by the present method.

F. C. Lynch[5] spoke of his experience as an engineering educator in the Westinghouse Company, and the fact that he had frequently been asked to explain what was wrong with the engineering colleges.

He cited many instances that had come within his experience, where he and other engineering graduates had not known comparatively simple methods of actual engineering practice. He felt that the universities were wrong in their methods of education and should eliminate a lot of research, calculus, and other things the industrial men were not going to need and teach everyday facts of industry.

In closing, Dean Walker said that in the administration of engineering schools it was necessary to distinguish closely the various types of training. We dealt here with a complex problem, where students of different abilities and aims were thrown together in their efforts to fit themselves for useful work. The need of the type described by Professor Magruder was well known to all, and personally he had studied such men and their needs for many years. It was his belief that a type of training should be instituted, much less rigorous than the standard engineering course, and probably requiring not more than three years time, in order to give them the best service. But the standard school, committed chiefly to the program of training professional engineers, would be laboring under difficulties if it organized a simplified and shorter course along-side of the rigorous one. Most boys would want to try for the more complete program, and this meant that the short program would become a dumping ground for the inefficient. This did not make for good morale. There was also the financial question, which prohibited many institutions from operating two distinct types of work.

It was necessary to take issue with Mr. Lynch. The professional engineering school was not the place in which to learn the tricks of the machinist's trade. Engineering educators had spent much time and effort in discussion and conference with industrial leaders and employers of engineering graduates. In these investigations, scores of employers had repeated the opinion that they wanted men thoroughly trained in the fundamentals of mathematics and science, and that they preferred to take the graduates, most of them from a four-year course, and give them their training in the special practices in the production departments. The schools could not do everything. The amount of shop work that it was possible to put into the four-year course in mechanical engineering amounted to about 300 actual hours, or less than 40 days. Machinists were not trained in 40 days, and the employers must expect to supplement school training and production methods for those graduates whom they intended to use in such lines of work.

Still another phase of engineering-school activity was that of general education for the public. In his own institution they were constantly trying to serve as a center of industrial information, in such ways as speaking at meetings of Chambers of Commerce over the state. They were also making special studies of local industrial conditions, keeping contact with the organized industries, publishing pamphlets and articles in the newspaper press, and in every way possible bringing out the sound economic facts of industry. They felt that progress was being made in that line.

[5] Director, Kansas City Safety Council, Kansas City, Mo.

Industrial Problems or Difficulties

A True Basis for the Development of Foremen

By L. A. Hartley,[1] Chicago, Ill.

In this paper the author discusses the subject of foreman training in the experimental, or textbook, stage, and shows the progress that is being made in attempts to arrive at a more satisfactory method. He shows that industrialists and educators agree that the problem is the basis of all instruction. Three common errors are discussed, namely, the error of ignoring specific problems, the error of analysis without synthesis, and the error of overemphasizing the foreman's teaching. Other subjects discussed are: human relations the foreman's problem; the foreman's need of science and sense; sharing of difficulties and defeats; management's part in the program; and methods of procedure.

Foreman training, as well as all other vocational education, is as old as the vocation. Professional vocational educators entering the field have "discovered" the foreman and proceeded to propose various methods for "training" him. These methods vary from adaptations of haphazard round-table conferences, already well known, to so-called "training courses" based upon books and bulletins. Many experiments are to be observed in this field, and a majority involve a generous use of texts. Systematic foreman training has reached that point in progress which students of the history of education will recognize as the textbook stage of development.

The market is flooded with books dealing with the subject. Writers whose experiences vary from reporting the daily news to furnishing articles for trade magazines, find ready sale for topics inspired by interviews with industrialists. More serious discussions of the subject are being generously prepared by industrial and educational leaders. A body of subject-matter is being developed which will sometime be used effectively as reference material. At present, there is a marked tendency to use one book or series of books or bulletins as a source of inspiration and authority.

Progressive Schools Discarding Text Methods

It is to be expected that the specialist in education will have passed a given point in educational procedure in advance of the industrialist whose major attention has been devoted to production. It is natural also that persons advancing in the field of foreman training should appreciate their progress even though they follow a beaten pathway over which progressive educators have long since passed. One of the older landmarks in educational advancement was instruction by text material.

A generation has passed since educators believed minds could be effectively trained through textbook methods for functioning in a real world. The attempt to separate mental and physical processes has always led to sterility of mind and starvation of body. On the other hand, there are unquestionably two processes—one mental and the other physical—in any industrial activity. While it is fatal to separate them, it is wise to consider each separately when organizing an industrial program.

The futility of attempting to train minds by means of texts has long been recognized. Dr. Strayer, in The Teaching Process, published in 1912, said:

> There is great danger in the use of textbooks that children and teachers will become satisfied with words, that they will come to think that the repetition of the formula is proof of knowledge. Textbooks are all too often merely books of texts.

Dr. John Dewey, in How We Think, 1910, concludes a discussion of certain evils in the schools of that period, from kindergarten to college, with the question:

> How shall we treat the subject-matter supplied by textbook and teacher so that it shall rank as material for reflective inquiry, not as ready-made intellectual pabulum to be accepted and swallowed just as supplied by the stores?

Industrialists as well as educators have recognized the weakness of dependence upon text material. Russell N. Keppel, Director of Training, Standard Oil Company, Bayonne, N. J., in Industrial Education Circular No. 9, published by the Department of Interior, Bureau of Education, January, 1922, says:

> When printed matter is used as a text by instructors in industry it is, in my opinion, a poor substitute for the work that they themselves should perform. In some cases it is a good substitute for poor instructors, and perhaps its use as a substitute for the instructor or as a crutch for lame instructors to lean upon is its most prevalent and most abused function in many industrial training departments and schools.

The testimony of thousands of industrialists could be introduced to emphasize this danger. It is believed that sufficient evidence has been put forward to warrant constructive suggestions for procedure. These suggestions center about the difficulty recognized in daily life.

Educators Turning to Problem Education

Recent publications by leading educators emphasize the problem as a basis for all instruction. In Principles of Education, by J. Crosby Chapman and George S. Counts, 1924, we read:

> Problems, problems and again problems should be the basis of instruction. All the orthodox subject-matter of the school should be examined to see the manner in which its essential elements can be taught around problems which grow wider and wider in their scope and demands.

These educational authorities suggest that eventually the mature student must be responsible for: 1, Realizing and stating his own problem; 2, Collecting information to solve the problem; 3, Self-criticism in the various steps of the solution.

The training programs in industry offer unexcelled opportunities for education through problem solution. Too often, in the past, these have been overlooked. W. J. Donald, Managing Director, American Management Association, writing upon the subject Man-Management, 1923, shows understanding of educational trends and possibilities. He says:

> When corporations began, ten or twenty years ago, to carry on training within companies for employees they copied from the schools the pedagogical methods which were then in vogue in the schools. Many directors of company education knew nothing of pedagogy and simply followed blindly the current school methods. Yet at this time there were leaders in educational theory who were searching for means to carry on education in a natural life situation and who would have given their eye teeth for the opportunity which was right at the hand of the company director of training.

What possible excuse can there be for attempting to change the "natural life situation" in industry, so necessary to human development, to the artificial situation from which even schools are trying to escape?

The Problem Basis for Training Foremen

Originality is not claimed for suggesting the daily problem, or difficulty, as a basis for the development of foremen. It is seen that this method has long been advocated by leading educators. The method is not even a modern one. Great teachers are distinguished for doing assignments. Jesus always concluded by directing his followers to go do something. Artists are largely responsible for the mental picture of Plato in the midst of a passive group of students. His Republic does not warrant such conception. Socrates would never have been condemned to death for merely organizing a conference of youthful Athenians to discuss abstract philosophical subjects. Seneca's culture divorced from purposeful activity produced Nero. Gamaliel the Elder, teaching philosophy and science in relationship to tent making, gave to the world Paul the Apostle.

There is a well-known parallel between hunger for food and interest in an idea. When a foreman has an unsolved problem

[1] Director of Education, National Founders Association.

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he is in no mental condition to gracefully entertain unrelated ideas. Even slightly unrelated ideas are somewhat objectionable. To expect sustained interest upon the part of a foreman in even partially related ideas is comparable to expecting a day laborer to be satisfied with soup and salad when his appetite calls for meat and potatoes. The foreman's own unsolved difficulty insures his interest. His mental appetite is fully stimulated. This mental condition is recognized by the psychologist as most desirable for the presentation of new ideas. A fact more important to the industrialist is that the daily problem, or difficulty, is the exact point of profit or loss. From a social standpoint it is the point of contact with or departure from the rising curve of progress. Thus it is observed that industrialists and experienced educators are a unit in considering the every-day problem as a true basis for industrial education, and especially for foreman development.

When errors are promoted by interests having numerous contacts with public education furnishing *entrée* to local industry, industrial and public interest demands identification of these errors. Attention is directed to three of these errors commonly observed. A statement bearing on the use of specific problems of individual students is quoted from what is probably one of the best books on foreman training. The value of the book as reference material is unquestioned. Its author has contributed much to vocational education. Charles R. Allen, in the preface to The Foreman and His Job, says:

> It may be noted here that while this book deals more directly with the problems of a foreman in an industrial plant, the questions raised and the suggestions made apply almost exactly as well to any one who has supervisory, managerial, and instructing responsibilities whether in the plant or in the office or even in commercial establishments, and that the discussions deal in general with the problems that come into the field of any executive. *This is true, of course, because the problems with which any executive or supervisor has to deal are largely independent of the particular kind of work that he has under his direction.*

When it is realized that this misconception in italics (which are not in the original) has largely influenced formal foreman training, it is not far-fetched to say that systematic foreman development is yet in the experimental stage.

The Error of Analysis Without Synthesis

Another error is observed when less experienced educators invade the field of industrial training and resort to analysis of responsibilities and duties as a substitute for industrial experience. Human relations do not lend themselves well to detailed experimental analysis. It is only when it is understood that each human responsibility is a part of the total human relationship that responsibilities may be studied separately and then as parts of the whole.

One of the difficulties confronting modern industry arises precisely at this point. Technical experts, aided by science in developing modern equipment, have too often considered the man as the human attachment to pull the levers of the machine. Human analyses are unsafe until the analyst is able to keep synthesis uppermost in his mind. Analysis is as essential in human relations as in any science, but analyses performed in class rooms, with cards representing human beings and activities, by students who know little of actual working conditions are artificially dangerous. There is danger of the human factor being eclipsed by the test tube or card index. Educators will do well to forget the opinions regarding industry current thirty years ago and understand that the progressive modern industrialist is sincerely trying to find a way to make men while making a reasonable profit. This has been found even to be good business. While this objective will not satisfy the Utopian, who would probably reverse it to read, "Make money while making men," it is certainly worth recording that thousands of leading industrialists actually feel a responsibility to *make men while making money*.

Another misconception may be traced to those educators whose industrial experiences have at best included brief vacation periods. They frequently decide that the chief responsibility of a foreman which is amenable to training is his responsibility as a teacher. No one will deny that imparting of ideas is one of his responsibilities. It is sincerely believed, however, that the average effectiveness of foremen and teachers in public schools will not differ greatly. While doubtless the teacher will understand better the principles of teaching, his situation is so artificial that he may get less opportunity to apply them. Upon the other hand, the foreman may be quite unacquainted with teaching principles as such but has always at hand those purposeful activities which must be made use of in training workers. When these two advantages are compared, the conclusion may be reached that the average foreman is probably as much in need of instruction in the art of teaching as is the average teacher. Statements of leading educators seem to justify this conclusion.

Disregarding these facts, most of the "conferences" on "foremanship responsibilities" feature teaching methods. One "conference leader" gained quite a reputation by a simple demonstration of the steps of teaching while tying a knot in a string. Some of his followers became themselves quite adept in this demonstration.

Human Relations as the Foreman's Problems

There are many foremanship responsibilities of far more consequence than teaching as such. It is a hopeful sign that there are a few outstanding examples of conference leaders who are turning away from these less effective methods and toward the every-day problems of industry. The problems of human understanding are of major concern. The modern foreman stands for the management with the workers and for the workers with the management, and in all sincerity it may be said that at times he must stand for "an awful lot." Personnel departments as managerial devices can never replace the disappearing personal touch. Industrialists may not, and educators should not, be deceived; the foreman must be concerned to some degree with every question which faced the old-time owner who worked with his men. These questions are constantly becoming more varied. They are specific, and generalities will not satisfy. There are about 42,000,000 wage workers in America. Of these, not more than 4,000,000 are even passively members of any sort of organization pretending leadership among workers. The remaining 38,000,000 are absolutely leaderless, save as their foremen may be said to represent them with their management. What, then, shall the foreman do with such questions as "the open shop," "employee representation," "company union," "loan plans," "wage incentives," "pension programs," and hundreds of others which may arise in different industries according to the policy of the organization? The conviction is beginning to prevail among progressive industrialists that these questions cannot be dodged. These issues are assuming too large proportions to be successfully straddled.

Interpretation Requires Understanding

Employers are beginning to comprehend the material value of friendship. The modern owner can seldom know workers. The American Telephone and Telegraph Company has over 340,000 stockholders. Management is becoming a trustee. The foreman is the only every-day contact. He is a mirror reflecting management to worker and worker to management. This reflection involves interpretation. This cannot be mechanical. It must be based on understanding. If his understanding is warped or cracked, he will reflect warped and twisted conceptions. Does the company maintain a policy of private contract with its workers? Depend upon it, workers will interpret this important policy in the light of their foreman's acceptance.

How shall the factory become a symbol of friendly understanding? How can a thing of brick and stone and steel become a friend to men? It cannot shake hands nor wave a friendly greeting. It cannot smile. The foreman personifies the factory with the workers. How, then, may he be friendly and yet not familiar? How may he be firm and not belligerent? How shall he build friendships for the business and yet not weaken the organization so necessary to production?

These are questions of utmost importance. They cannot be learned separately from the operations as they are performed. Neither can they be taught through generalities which the foreman is left to apply without understanding. We may not hope for much help from the college in our program of developing foremen in this direction. A recent survey of the metal-trades in-

dustry revealed the fact that approximately 97.2 per cent of the foreman group are without college training. Foremen have arrived by the door of "hard knocks." There is no more loyal group. The foreman is by virtue of his upcoming about 99 per cent realist. He has learned to live in a real world.

The Foreman's Need of Science and Sense

It has been suggested that foremen would benefit greatly by the study of applied psychology. Well, who wouldn't? Most foremen study a number of subjects as they progress from overalls to supervision. Occasionally men will be found who seem wholly unfitted for advancement, although they are widely read and informed in many subjects. Students of psychology may become so interested in tracing the impulse from axon to dendrite or from dendrite to axon that they lose sight of the human obligations which are fundamental to race experience. They may, on the other hand, give so much attention to mechanical aptitudes that they forget the ambition and other factors that go to make up a whole human being.

If there is one prayer that the industrialist might offer more than another it should be to be saved from the psychologist or technician who is merely a psychologist or technician. Science has contributed much to industry, but common sense has contributed more. Let the foreman learn from all science as he has learned what he needs to know of medicine. This he has learned through first aid on the job. Progress is not indebted to those who repeat, parrot-like, "A little knowledge is a dangerous thing." That which sometimes passes for knowledge is incomplete in that it has not been tested. Much more is useless because it is unrelated. All knowledge is worth while to those who can make use of it. By all means let the foreman-development program make use of every scientific device and method and principle which can be brought to bear upon the situation. Make, however, the daily difficulty, or problem, the thing to be studied and let the scientific principle contribute to rather than dominate the educational process.

Foremen should not be expected to come running to their managers with their unsolved problems. It is characteristic of high-type persons that they hesitate to admit defeat. The dividing line between temporary difficulty and permanent defeat is not always clear. Foremen have demonstrated this tendency to fight their own battles. When the cost is not greater than warranted, this tendency is worthy of encouragement. The difficulty for management lies in the fact that it is human to consider unsolved difficulties as defeats. The managerial problem is to lead foremen to understand that the difficulty is a common one—that responsibility for solution and responsibility for defeat are shared by all alike.

Management's Part in Program

A prerequisite of systematic foreman development is an understanding by management that effective training of foremen will be reflected throughout the organization. If management is unwilling to enter into the enterprise with open-minded understanding that all of its policies which foremen enforce shall be frankly discussed, such an industrial organization is not ready to use daily problems and difficulties as a basis for any kind of employee training. Managers who labor under the delusion that "I am running this business," should not try this method. Furthermore, if management is satisfied with present methods of factory operation, except for the details of the foreman's work, there is not sufficient reason for undertaking this kind of training. As in the case of foremen, management should have a keen desire for and interest in the activity before it is attempted. Experience with upward of fifty programs suggests that in most cases management presents about as much opportunity as any other group.

Human engineering should be placed upon the same ethical and self-respecting basis as any other profession. The human engineer should maintain the same attitude toward an industry that an ethical physician maintains toward a prospective patient. Until management or stockholders realize a need for training, the human engineer should confine his attention to familiarizing owners and managers with symptoms of industrial instability. When managers or owners are ready to admit their own problems or difficulties is time enough to begin the secondary program. After all, the biggest job in industry is to get every one to think and say "we" and "our" and "us" instead of thinking "I" and "my" and "me." This must begin with management.

Methods of Procedure

Methods of procedure are fairly simple.

Step 1. Representatives of management in every major department, or, in the case of a comparatively small plant, the general superintendent, should meet with the engineer in charge of the program of contemplated development and prepare a comprehensive statement of organization difficulties. These should cover every department. The difficulties, or problems, having been stated, they should be recorded under the names of foremen who are interested in their solution. It is evident that most plant difficulties will appear in a number of these individual foreman records.

Step 2. The engineer in charge of the program should next prepare for his own use a series of notes on general topics covering the principles involved in the solution of each recorded difficulty. Each problem should be treated separately unless it is evident that the principles involved in different problems are quite similar in application. To each topic should be appended reasoning questions and page and paragraph references to reliable and available publications or statements dealing with the subjects. By reasoning questions are meant questions which cannot be answered by "yes" or "no," or by memorizing subject-matter, and which assure reasoning upon the subject. The references will be of such variety that every foreman can be helped on his problem, whatever his technical preparation. It is assumed that the one preparing the topics will have made a study of interested foremen. A better name for these topics might be lesson plans.

Step 3. Daily difficulties should be recorded by every foreman. This should be made a part of his routine, exactly as is the recording of orders for material. These statements need not be detailed. Blanks can be provided which will be found actually to replace much of the usual interdepartmental communication and to reduce the number of informal conferences between foremen and department heads. These brief records simply systemize present procedure and assure that foremen will have thought through the statements of problems before reporting. The daily difficulty form will be explained and passed out at the first foremen meeting in the program. The engineer in charge may need to expand the series of topics he has prepared.

Step 4. When foremen begin recording daily difficulties, these should be made subjects of immediate study by managerial representatives directly interested in their solution. The aim of this study should be to decide whether or not these difficulties will warrant further study by committees to be made up of directly interested foremen and specialists. If a difficulty is one which can be remedied without further study, it should be remedied at once without further investigation. Those difficulties requiring more general understanding to assure permanent solution should be recorded for further study by committees. There is an advantage sometimes in referring a problem to a committee which a specialist or representative of management can readily solve theoretically. One of the surest ways to destroy interest in the study of problems is for some official or engineer to be always giving a demonstration of his unusual ability. His recommendations should be given quietly to the management at once; and if the delay is not prohibitive, his ideas should be "sold" at an appropriate time to the committee to which the problem is to be assigned. (See step 6.) This committee study of a problem which a specialist can easily answer in theory is often necessary in order to discover the best methods of application. Furthermore, problems remain unsolved until practices are corrected.

Step 5. The next step is to assemble foremen for discussion of the general principles underlying problems. They should be assembled by the departments in which they function. It is human to recognize opportunities of other departments to correct their procedure. Representatives of management and specialists should be in attendance whenever their presence will aid in the accomplishment of the aim of the meetings. Topics, or notes, may, if convenient, be mimeographed and distributed a week in

advance of each meeting. General discussion of each topic should be shared in by each group and care should be observed that each member receives exactly that stimulation which will aid him in stating his daily difficulties. The aim of these general meetings should never be lost sight of by either the foremen or the one in charge of the meetings. The aim should be to assist each foreman to "realize and state his own problem."

Step 6. Committees should be assembled according to the exact distribution of interest in the solution of the problem. This may require a slight shifting from the arrangement in step 5. These committees should be assisted by the person in charge of the program. His aim in this connection should be twofold: (a) To act as a clearing house of information from various departmental sources, and (b) to observe the deliberations of the committees with a view to making recommendations to the original committee (see step 1) as to new general problems. The committees to which specific problems are assigned should be continued until they are ready to recommend a solution or until they reach a conclusion that the problem cannot be solved. In either event, each committee should conclude its work with a definite report of its conclusions, which should be referred to the management.

Step 7. The managerial committee should continue to function by recording from time to time new general difficulties as they are revealed. These difficulties, together with those which may have been developed during committee sessions, will become the bases for new subjects of study in another series of general meetings.

Step 8. Occasionally, when sufficient improvement has resulted to justify, plant assemblies of foremen and executives should be held for the express purpose of recognizing the contributions of committees. Certain leading workers who may be in line for promotion should be invited to these meetings as a mark of esteem. Great care should be observed that only outstanding improvements are recognized and that the committee is honored rather than some one or more members.

Summary

In conclusion, it is in order to remark that the program is based upon the well-known fact that very few, if any, intelligent persons do as well as they know. This is an outstanding observation concerning industrial organizations. The central idea of this development program is to provide a channel for disseminating information possessed by those who are best informed, the dissemination to be carried to the point of application. It has the merit of developing the foreman while improving production and distribution without the foreman being made to feel that his own training is the objective. In committee, the humblest foreman will rub shoulders with metallurgists, power engineers, rate men, storekeepers, superintendents, employment managers, apprentice supervisors, and any others who may be directly interested in the problem being studied at the time. This will be found beneficial to all concerned. The program provides escape from the deadly aftermath which follows the ordinary foreman-training course based upon the study of even the best texts. This is well expressed in the words of an executive who had enthusiastically supported one of these "courses." He said: "It went along smoothly at the start, then the foremen seemed to kind of lose interest, and finally it seemed to just run out of gas." Such performances are not conducive to further training.

The *project method of foreman training* is not untried. It is not an innovation. Experienced industrialists will see in it many traces of their own methods followed in emergencies. These methods are merely organized systematically. The program becomes a part of the practice of the organization. It can be used in any plant regardless of size or product. Subject-matter of all kinds may be used regardless of the label or source, provided it passes the inspection of those in charge of the activity and bears directly upon the problem being studied. The program will continue automatically as long as there is a recognized industrial problem. When a condition is achieved in which no problems can be found, it is earnestly believed that the foremen should be granted a short vacation from study while the one in charge of the enterprise probes for new difficulties.

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Discussion

P. F. WALKER read extracts from a letter received from C. M. Miller, Director of the State Board for Vocational Education at Topeka, Kansas. In this letter Mr. Miller expressed the view that Mr. Hartley's plan differed greatly from the opinions of the Federal and many state boards for vocational education. But he agreed with Mr. Hartley that the only proper method of initiating a foreman training program was to have them gathered together under a proper leader to use their own experience and problems as the basis for study. This, he said, might then be supplemented and continued by certain courses of more academic nature. He emphazied the importance of having this conference without the presence of the management in order not to curb the free expression of the foremen.

He criticised Mr. Hartley's plan as intended to work out and put into operation the company's propaganda. He said that Mr. Hartley took the position "that a foreman is good or bad, that he is well trained or poorly trained to the extent that he seeks, at all costs, to further company policies regardless of the men working under him."

Dean Walker then said that the papers and discussion had impressed him with the fact that the educational work was only a part of management and invited all present to the next day's session on management, which would be a continuation of the line of discussion.

Referring to Mr. Miller's criticism, he said that his experience had been that where the management was sound and was working with the ideals and aspirations expressed in Mr. Hartley's paper, the presence of management at the "shop committee" meetings had been most successful. He referred to the General Electric Company, which he had studied most thoroughly, as getting apparently excellent results.

The criticisms made of technical graduates during the discussion of Mr. Thomas' paper,[2] he felt, did not signify a belief that the graduate mechanical engineer was not satisfactory. He said, that to supply the calls that had come to him as the head of the School of Engineering of the University of Kansas would require

[2] See pp. 886–888 of this issue.

two or three times the number of graduates available and that Professor Magruder had expressed to him an even stronger demand at Ohio State University. It was this tremendous demand, he explained, that reduced the number who went to the railroads.

To show how big were the gains made by technical graduates, he referred to a study made by the National Industrial Conference Board which showed that about fifteen years after graduation two-thirds of the technical graduates were occupying executive positions. He expressed the opinion that leaders were so in demand in industry that those with natural qualifications were given executive positions whether trained by colleges or by the industries themselves.

C. Y. Thomas expressed a considerable disagreement with the plans under discussion by citing an expression made recently at a session of the International Railway General Foremen's convention. After four or five hours devoted to discussing foremen's training one of the those present had stated, "I think about ninety-nine per cent of this foremen training is all bunk." Mr. Thomas said that this was his view and apparently the view of seventy-five per cent of the group.

He went on to say that during the last three or four years at Pittsburgh, where he was located, and where the mechanical department consisted of about 30 supervisors, blacksmiths, boilermakers, machinists and others, his company had found that the average foreman was not capable of going ahead with the training.

He expressed the opinion that such training might be successful if all the men were around the age of thirty to thirty-five and doing the same class of work in the same trades and similar departments. He did not feel that it would work with a group much varied as to age and occupation. He felt that it was the employer's biggest function to provide some method, possibly a superior method of individual study, by which the man who wanted to get ahead need not be fettered by the apparent apathy of others.

In response to a question by Mr. Thomas, Mr. Hartley explained that his plans did not propose taking different men from different industries and training them together. He also referred to a study he had made for the John Deere Company at Moline, Ill., along this line and suggested that his recommendations, which he did not feel at liberty to reveal, could probably be obtained by application to one of the officials of the company.

B. E. Short[3] described a plan that the Texas Oil Company had used in trying to improve their foremen. This consisted of listing various problems brought up by foremen and letting the other foremen answer them at regular weekly meetings.

Mr. Thomas said that in his view it was essential for a foreman to produce and make his men produce, after which other virtues could be added. He felt it would be a long time before all the necessary elements could be introduced in the training of foremen. He expressed the view that the training of foreman should be essentially the training of young men to fit them for the position and selecting the ones that showed the greatest promise.

He said that his college training made him able to think a little more and grasp the problems a little more quickly; but that his real education came through the human element, contact in the apprenticeship with the managers and officers of the road. He expressed the wish that the college men would stick to the railroad work, which he described as the most exacting outside the army and navy, as the government told the railroads what they could charge and what they must pay their men.

Walter C. Thee[4] discussed the school started by the quartermaster Corps, U.S.A., at Camp Holabird, Md., to train the personnel for its reconstruction park. Here some 500 enlisted men, members of the Motor Repair Battalion, were engaged under departments covering almost every conceivable line of repair. Lieutenant Thee confined his discussion to the training of foremen exclusively.

The foremen at the head of these departments were non-commissioned officers, usually with many years of service. As they were given a course of instruction in the trade they were most interested in when they first entered the Motor Transportation Branch they understood the work they were directing. The main purpose of the school was therefore to give additional information and training regarding new developments, changes in production methods, shop management, aims and policies of the shop, etc.

[3] Instructor, University of Texas, Austin, Texas.

[4] First Lieut., Quartermaster Corps, U.S.A. Assoc-Mem. A.S.M.E.

In starting the school the first step was to prepare (from the mass of written material available) a schedule covering the subjects of which a working knowledge was advisable. Upon this schedule two series of lectures were prepared. The first covered industrial management, including leadership, handling of men, the study of human behavior, etc. The other series covered scheduling and routing work through the shops.

Lieutenant Thee further explained that in order to have these lectures confined to the needs of the students, they were specially prepared and dealt with the organization's aims and policies, with a purpose of assisting the higher administration to accomplish its mission. The students were the foremen and assistant foremen of the various departments. The various problems and difficulties that came up in the shop were taken up in the class room.

The instructors were the executives in charge of the subjects treated. Thus the executive in charge of production dealt with the aims and policies of the organization. Scheduling and routing and inspection were dealt with by the appropriate executive, while the executive in charge of the training division prepared the schedule and took charge of all subjects not common to other divisions or for which no other executive was particularly trained.

In his closure Mr. Hartley referred to the report of the National Industrial Conference Board on "Technical Education and the Metal Trades Industries." To overcome the apparent contradiction that arose wherever this report was discussed he explained that only about two per cent of the children who entered the primary grades finished college, and that with this small percentage, seventeen per cent of the positions of importance in the metal-trades industries being filled by college men was really a credit to the college men.

In commenting on the criticism of Mr. Miller, whose opinion, he said, he valued highly, he declared his committee would certainly hesitate to endorse any sort of training program that barred the management from the conference of the foremen when it began to take up the problems that the foremen had to consider. He said there was no quicker way to commit industrial suicide than that.

Discussion at Railroad Session

(*Continued from page 870*)

that this difference was greater than the difference of the heat of the live and exhaust steam which was proportional to the useful work, due to throttling, etc.

At 200 lb. per sq. in. pressure, 250 deg. superheat, 10 lb. per sq. in. exhaust pressure (gage), and assuming 75 lb. of steam per lb. of coal, which assumed an overall boiler efficiency of 66 per cent at a firing rate of 90 lb. per sq. ft. of grate, the total heat content per lb. of coal $1296 \times 7 = 9080$ B.t.u. per lb. of coal. The corresponding entropy referred from 70 deg. feed temperature was 1.61.

The unavailable energy was $7 \times 530 \times 1.61 = 5908$ B.t.u. per lb. of coal.

The available energy was $9080 - 5980 = 3100$ B.t.u. per lb. of coal.

The total heat of the exhaust steam, assuming 30 deg. superheat, was $1122.4 \times 7 = 7871.2$ B.t.u. per lb. of coal, and the entropy was 1.79 referred from 70 deg. fahr.

The unavailable energy was $7 \times 530 \times 1.79 = 6650$ B.t.u. per lb. of coal.

The available energy was $7857 - 6650 = 1207$ B.t.u. per lb. of coal. The useful work performed was $9080 - 7871 =$ B.t.u. per lb. of coal.

If we allowed for mechanical losses external to the steam circuit with 80 per cent efficiency, the net work was 967.2 B.t.u. per lb. of coal, or an overall efficiency of 7 per cent.

The change of availability was $3100 - 1207 = 1893$ B.t.u. per lb. of coal. Therefore the loss due to throttling was $1893 - 1209 = 684$ B.t.u. The engine-cycle overall thermoefficiency was therefore 64 per cent.

Loss of Energy in Heat Transmission. This important loss could now be estimated. It was the available energy for heat transmission minus the available heat in the steam; that was, $7374 - 3100 = 4274$ B.t.u. per lb. of coal.

Heat Transfer Through Insulation in the Moderate- and High-Temperature Fields: A Statement of Existing Data

By L. B. McMillAN,[1] New York, N. Y.

The purpose of this paper is to set forth briefly the state of existing knowledge on heat transfer through insulating materials in the moderate- and high-temperature fields as indicated by the literature on the subject; to show in what respects this knowledge is insufficient; and to point out the directions in which future research work is most urgently needed.

It is not a review of the literature in the sense of attempting to abstract various articles and statements, but after a comprehensive survey an endeavor has been made to present a complete picture of the information available and to point out what is lacking. In addition the effort is made in some cases to supply needed information not now available in the literature. In this connection the method of determining mean temperatures, and the economic data in particular, are entirely new and original. Furthermore, the whole subject is presented from a new point of view.

The particular field of this research is the literature referring to heat transfer through insulation in the temperature range between the refrigeration field on the one hand and the refractories field on the other, with the specific exception of literature pertaining to heat transfer through building materials, which is covered by another National Research Council Heat Transfer Committee assignment, and which will be reported on separately by another author. Still other assignments cover the literature of heat transfer in the refractories field and in the refrigeration field. These likewise are being reported on by other authors.

The fundamental theory of heat transfer in the steady state (uniform temperature conditions maintained at both warmer and cooler surfaces) has been well known throughout the past century by the leading authorities on heat transfer. Briefly, it is based on the same conception as Ohm's law: namely, that flow varies directly as the potential and inversely as the resistance. On the other hand, the lack of such thorough understanding of basic principles by many who have written on the subject is responsible for the state of the literature which, by some, is considered chaotic. The author is not inclined to such a gloomy view of the entire literature, however. It is true that in referring to the literature one must be able to differentiate between the sound and the unsubstantial, but this is also true of the literature of any subject, where it is as voluminous as in this case.

Definitions and Equations

Case I—Simplest Heat-Transfer Equation, Flat Surfaces. The resistance to heat transfer is dependent upon the thickness x and conductivity k. It varies directly as the thickness and inversely as the conductivity, and is equal to x/k. Therefore the simplest case of heat transfer through a material having flat surfaces is represented by the equation

$$U = \frac{t_1 - t_2}{\dfrac{x}{k}} \qquad [1]$$

in which U is the overall rate of heat transfer in B.t.u. per sq. ft. per hr., t_1 the temperature of the warmer surface, and t_2 the temperature of the cooler surface.

Conductivity. Thermal conductivity is defined as rate of heat transfer in one direction (perpendicular to an area) per unit area, per unit temperature differential per unit thickness, per unit time (B.t.u. per sq. ft., per degree temperature difference between surfaces per 1 in. thickness, per hr.).

Conductivity is a specific property of a material. It is not dependent on the area, thickness, or shape of the material. It is a *rate*, not a *quantity*. The total quantity of heat transmitted is dependent upon the area, shape, and length of path (thickness of material), but conductivity is not. Conductivity is dependent upon temperature, but this is also true of other specific properties of material, density for example. This relationship of conductivity and temperature will be discussed in detail later.

The phrase "in one direction" has been added to the usual definition of conductivity for two reasons. First, because some materials, wood for example, may have different conductivities in different directions; and second, and more particularly, to warn the unwary to take account of conditions involved on curved surfaces in the portion of the equation dealing with the shape of the path and not in the conductivity itself.

Case II—One Material and One Surface Resistance. Flat Surface. Often the temperature of the cooler surface is not known, the known temperatures being those of the warmer surface, t_1, and of the air surrounding the cooler surface, t_a. Then the rate of heat transfer is given by the equation

$$U = \frac{t_1 - t_a}{\dfrac{x}{k} + \dfrac{1}{c}} \qquad [2]$$

in which c is the rate of heat transfer from outer surface to air.

Surface Resistance. The term x/k represents the resistance of the material in question, and the term $1/c$ represents the *surface resistance.* The lack of thorough understanding of the effect of surface resistance is perhaps responsible for more confusion in the literature of heat transfer than any other single item. The failure to separate the effects of *surface resistance* from those of *insulation resistance* is the cause of most of the conflicting conceptions of conductivity.

In some cases surface resistance is the controlling factor in total rate of heat transmission. Fortunately for the solution of insulation problems the value of surface resistance is usually small as compared with the insulation resistance—usually less than 25 per cent, and frequently less than 10 per cent of the insulation resistance. Therefore, with even approximate data on surface resistances, such problems may be solved with a very satisfactory degree of accuracy.

But the case of heat transfer from bare surfaces at high temperatures and at varying air velocities is quite another matter. It would be difficult to find a more interesting or more fruitful field for physical research. But if such research is to be of permanent value it must be directed along other lines than those generally followed in the past. It must take into account the absolute temperatures of the surface and surrounding objects, and it must take separately into account the effects of radiation and convection, and the effect on the latter of air velocity and extent and position of the surface. The work of Langmuir[2] is an excellent illustration of the direction in which to proceed, but the work must be carried much farther if the results are to be of real service in the engineering field.

Case III—One Material, Two Surface Resistances, Flat Surface. When the temperature of neither the inner nor outer surface is known, and the known temperatures are those of the air on either side of the insulation, the equation for heat transfer is

$$U = \frac{t_0 - t_a}{\dfrac{1}{c_1} + \dfrac{x}{k} + \dfrac{1}{c_2}} \qquad [3]$$

[1] Chief Engineer, Johns-Manville Corporation. Mem. A.S.M.E.

Presented at the Annual Meeting, New York, December 6 to 9, 1926, of The American Society of Mechanical Engineers, at a joint session with the American Society of Refrigerating Engineers. Abridged. Program arranged by the Committee on Heat Transmission, National Research Council.

[2] Trans. Am. Electrochem. Soc., vol. 23.

in which t_0 is the temperature of the air on the warmer side, c_1 the rate of heat transfer from air to surface on the warmer side, and c_2 the rate of heat transfer from cooler surface to surrounding air.

The inside surface resistance, $1/c_1$, is not used when the temperature of the warmer surface is known. Also, its magnitude is often negligible where effective insulation is placed directly against a heated surface the temperature of which is known. However, it is included in these general equations in order that it be not neglected in cases where it should be taken into account.

Case IV—Two or More Materials, Flat Surface. So far only one material has been considered. If heat must flow successively

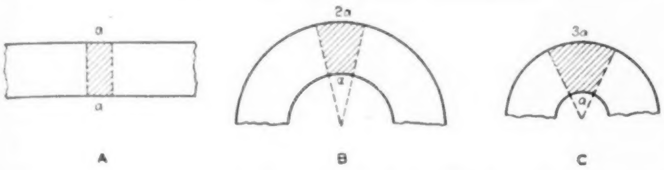


Fig. 1 Areas of Paths for Heat Flow Through Insulations on Flat and Cylindrical Surfaces

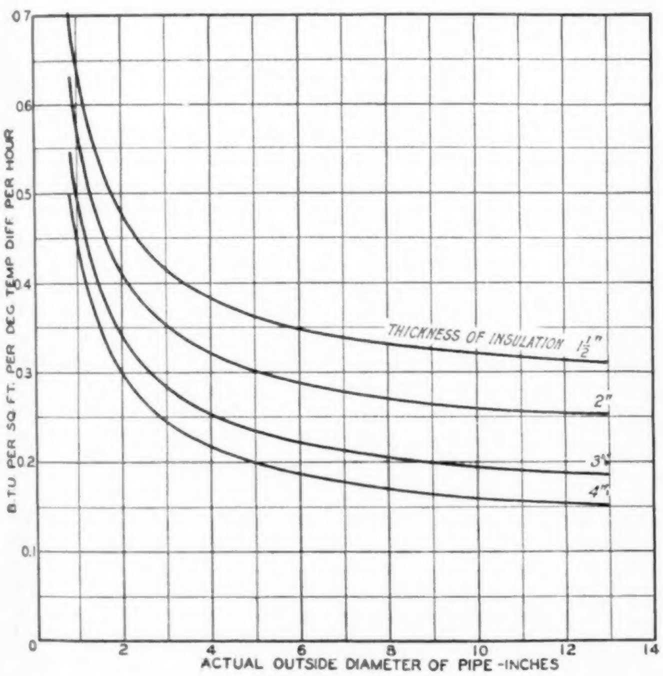


Fig. 2 Variation with Pipe Size of Rate of Heat Transfer Through a Given Thickness of Insulation

through two or more different materials, the equation takes the form

$$U = \frac{t_0 - t_a}{\dfrac{1}{c_1} + \dfrac{x_1}{k_1} + \dfrac{x_2}{k_2} + \dfrac{x_3}{k_3} + \ldots + \dfrac{1}{c_2}} \quad \ldots\ldots\ldots\ldots [4]$$

in which x_1, x_2, x_3, ... etc., are the thicknesses of the various materials, and k_1, k_2, k_3, etc., are the conductivities of the respective materials.

Inspection of Equations [1] to [4] shows that they are all of the same form. When heat must flow successively through various elements of the construction, in order to write the equation for heat transfer all that is necessary is to add to the equation an item representing the resistance of each successive element.

Cylindrical Surfaces.[3] Except on flat surfaces, the internal resistance of a material does not vary directly as the thickness. In the case of cylindrical surfaces, increasing the thickness supplies additional resistance through which the heat must flow, but at the same time increases the area of the path through which the heat may flow. This is illustrated in Fig. 1, which shows the areas of paths for flat and cylindrical surfaces. It is clearly apparent from this diagram that the heat transfer per unit of area of inner surface will be greater for insulation on a curved than on a flat surface, and that the smaller the radius of curvature, the greater will be the rate of heat transfer per unit of inner surface area.

Case V—One Material, Cylindrical Surfaces. The rate of heat transfer per hour, per square foot of outer surface, through a single layer of uniform material on a cylindrical surface, when the temperatures of the two surfaces are known, is given by the equation

$$U_2 = \frac{t_1 - t_2}{\dfrac{r_2 \log_e \dfrac{r_2}{r_1}}{k}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [5]$$

in which t_1 and t_2 are the temperatures of the warmer and cooler surfaces, respectively, r_1 is the external radius of the pipe or cylinder and r_2 is the radius of the outer surface of the insulation.

The loss per square foot of pipe surface is

$$U_1 = \frac{r_2}{r_1} \times U_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots [5a]$$

in which U_1 and U_2 represent the rates of heat transfer per hour per square foot of pipe surface and outer surface of insulation, respectively.

It will be noted that the expression $r_2 \log_e (r_2/r_1)$ occupies the same position in Equation [5] that the thickness x occupies in Equation [1]. In fact, this expression is frequently referred to, for convenience, as "equivalent thickness." It is numerically equal to the thickness of material on a flat surface which would be required to give the same rate of heat transfer as that per square foot of outer surface of insulation on the cylinder or pipe. With this fact in mind, a like relationship will immediately be apparent between Equations [6], [7], and [8], which follow, and the corresponding equations for flat surfaces applying to similar conditions. Therefore these equations are not nearly so formidable as they appear.

Case VI—One Material, Cylindrical Surface, One Surface Resistance. When the temperature of the cooler surface is not known the equation becomes

$$U_2 = \frac{t_1 - t_a}{\dfrac{r_2 \log_e \dfrac{r_2}{r_1}}{k} + \dfrac{1}{c}} \quad \ldots\ldots\ldots\ldots\ldots [6]$$

In the preceding equation all terms have the same significance as in Cases II and V, respectively. To obtain rate of heat transfer per unit of pipe surface, use Equation [5a].

The effect of pipe size on the rates of heat transfer through insulation per square foot of pipe surface under the conditions of Case VI, is illustrated in Fig. 2. It will be noted that the rate of heat transfer through 2-in.-thick insulation on $^1/_2$-in. pipe is more than twice as great as that through the same thickness of insulation on 12-in. pipe.

Case VII—One Material, Cylindrical Surface, Two Surface Resistances.

$$U_2 = \frac{t_0 - t_a}{\dfrac{r_2}{r_1} \times \dfrac{1}{c_1} + \dfrac{r_2 \log_e \dfrac{r_2}{r_1}}{k} + \dfrac{1}{c_2}} \quad \ldots\ldots\ldots [7]$$

in which all terms have the same significance as in Cases III and V, respectively. As before, $U_1 = r_2/r_1 \times U_2$.

Case VIII—Two or More Materials, Cylindrical Surfaces, Two Surface Resistances.

$$U_s = \frac{t_0 - t_a}{\dfrac{r_s}{r_1} \times \dfrac{1}{c_1} + \dfrac{r_s \log_e \dfrac{r_2}{r_1}}{k_1} + \dfrac{r_s \log_e \dfrac{r_3}{r_2}}{k_2} + \dfrac{r_s \log_e \dfrac{r_4}{r_3}}{k_3} + \ldots + \dfrac{1}{c_2}} \quad \ldots [8]$$

[3] Equations of the type of [5] to [8a], inclusive, were outlined by the author in a discussion in *Jl. Am. Soc. Heat. & Vent. Engrs.*, July, 1920, p. 571.

$$U_1 = \frac{r_s}{r_1} \times U_s \qquad [8a]$$

in which r_s is the radius of the outer surface of insulation and U_s the rate of heat transfer per hour per square foot of this surface. Other terms have the same significance as in previous equations.

Temperature at Any Point. The temperature drop through each element of the construction bears the same ratio to the total temperature drop as the resistance of that element bears to the total resistance. Therefore, since the terms in the denominator of each of Equations [2], [3], [4], [6], [7], and [8] are the respective resistances to heat flow offered by the individual elements in the construction, this form of equation lends itself very conveniently to the calculation of the temperature at any point in the construction.

Small Cylinders. In the case of small cylinders, such as wires, the increased area of path for heat flow through covering material often overbalances the added resistance through which the heat must flow. In such a case, applying material on the surface of the cylinder will increase the loss until the thickness has been built up to the point where the outside radius

$$r_2 = \frac{k}{c} = R_s k \qquad [9]$$

after which the addition of still more material will decrease the rates of heat transfer. (Appendix 2 of the complete paper gives the derivation of this equation.) If the radius of the cylinder itself is greater than k/c, the application of covering material will decrease the rate of heat transfer from the outset. For example, if the conductivity of the covering material k is 0.2 B.t.u. per sq. ft., per deg. temperature difference per 1 in. thickness, per hr., and the rate of heat transfer from surface to air c is 1.67 B.t.u. per sq. ft. per deg. temperature difference per hr., the loss will be decreased from the outset by the application of covering in all cases where the outside radius of the cylinder is greater than 0.30 in.

While the matter of losses from small cylinders is of great importance in connection with electrical insulation on wires, it is of little practical importance in connection with heat insulation.

Conductivity—A Function of Temperature

Conductivity has already been defined at the outset of this paper, and was there shown to be a specific property, not dependent upon the area, shape, or thickness of the material. It has long been recognized that the conductivities of insulating materials are higher at the higher temperatures. It is reasonable that this should be so; because, due to the porosity of their structure, heat is transferred within these small spaces by radiation, convection, and conduction, in addition to that conducted by the solid particles in actual contact, and both radiation and convection increase more rapidly than the first power of the temperature.

It is well known that insulating materials owe their insulating value to the porosity referred to above, and often it is said that the air spaces are responsible for the low conductivity. That is true as far as it goes, but a more complete statement of the situation would be that it is the multitude of surface resistances at the boundaries of the air spaces which give the material its resistance to heat flow. Because of the close proximity of the warmer and cooler walls of these spaces, the magnitude of each of these surface resistances is naturally small as compared with the resistance at an outer surface, yet because of their multitudinous number the sum of all of these small resistances may result in a total resistance of relatively high magnitude. The solid material between the spaces may be relatively a good conductor of heat, yet if the physical structure of the particles be such as to provide a sufficient number of spaces with their corresponding surface resistances, the resulting product may be a very good insulation. This is illustrated by the fact that the conductivity of magnesium carbonate in the form in which it is used as an insulation is about one-thirtieth of that of the same material in solid form. An even more striking example is the case of carbon, which in the form of graphite has a conductivity of more than two hundred times that of carbon in the form of lampblack.

The effect of temperature on conductivity has been taken into account by different investigators in various ways. The four most common methods of expressing conductivity are as follows:

- *a* As a function of temperature difference between surfaces
- *b* As a function of the temperature of the warmer surface
- *c* As a function of temperature difference between warmer surface and room temperature
- *d* As a function of mean temperature.

Since conductivity is a function of temperature, the correct basis of expressing its value is in terms of conductivity at the mean temperature of the material [method (*d*)]. This mean temperature is the arithmetical mean of the temperatures of the two surfaces and is not the temperature at the physical center of the material.

Carl Hering[4] and L. L. Barrett[5] have shown that where the curve of conductivity with respect to temperature is a straight line, the average conductivity for the entire thickness of material under consideration is equal to the true conductivity at the arithmetical mean of the two surface temperatures. The author has shown[6] that this relationship applies with a satisfactory degree of accuracy to conductivity curves of considerable curvature as well as to straight lines. The average conductivity is equal to the true conductivity at the temperature

$$T = \sqrt[n]{\frac{T_2^{n+1} - T_2^{n+1}}{(n+1)(T_1 - T_2)}} \qquad [11]$$

but the arithmetical mean of the surface temperatures closely approximates the value of this expression for a considerable range of values of n. (See Appendix 3 to the complete paper for proof of this proposition.) This proof also shows that the relationship holds for either flat or curved surfaces.

Conductivities expressed in this way may be used in computations involving a given layer of material regardless of whether it is used alone or in combination with other layers of material. All that is necessary is that the mean temperature of the layer of material be known. In the past it has usually been necessary to arrive at this mean temperature by the "cut and try" method, which was quite tedious. However, in his own work the author has used for several years past a method whereby the mean temperature of each layer of material in combinations of two materials may be determined graphically with a highly satisfactory degree of accuracy. This method makes the computations for combinations of two materials extremely simple and may be extended to minimize the "cut and try" required for any number of materials. However, usually there are not more than two materials of major insulating value in a given construction.

The method is illustrated in Fig. 3, which is based on the conductivities of Superex[7] and 85 per cent Magnesia, shown in Fig. 4. Briefly, the chart is based on plotting the temperature gradients through the two materials, using a scale of thickness for one of the materials sufficiently different from that of the other so that, when plotted, the temperature of the warmer surface of the first material, the temperature of the surface of contact between the two materials and the temperature of the cooler surface of the second material will all lie on the same straight line. Obviously if the conductivities of the materials are different, these points will not lie on a single straight line when plotted to the same scale of thickness. However, if the scales of thickness for the two materials be made in inverse proportion to their conductivities (scale for first material equals k_2/k_1 times the scale for second material) the three points will lie on the same straight line.

The construction of this chart is illustrated in Fig. 5, where the actual temperature gradients plotted to a uniform scale of thickness are indicated by the solid curved lines. It has already been shown that the average conductivity for each layer is the conductivity at the arithmetical mean of the temperatures of the two surfaces, and is not the conductivity at the physical center of the material. Therefore, the actual shapes of the gradients be-

[4] Trans. Am. Electrochem. Soc., vol. 21, p. 520.
[5] Trans. A.S.M.E., vol. 44, (1922), p. 315.
[6] Mechanical Engineering, Oct., 1924, p. 603.
[7] A recent development in high-temperature insulating material for temperatures from 500 to 1500 deg. fahr.

tween EF and FG are mainly of academic interest, and the locations of the points E, F, and G are the vital considerations in the solution. The dotted line CH represents the thickness of the first material equal to OA, but plotted to a scale which will cause the three controlling temperatures to fall on a straight line.

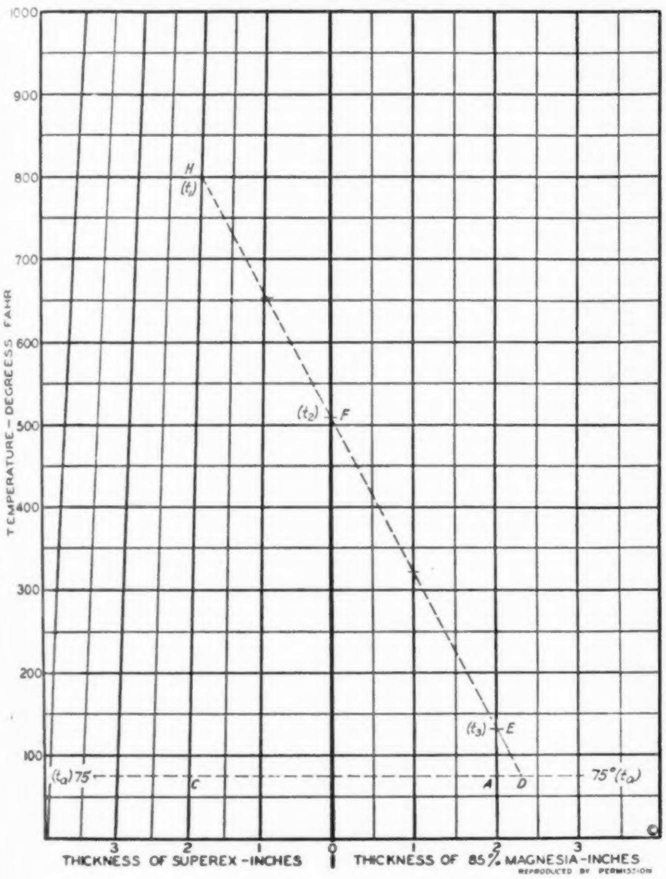


FIG. 3 MEAN-TEMPERATURE CHART

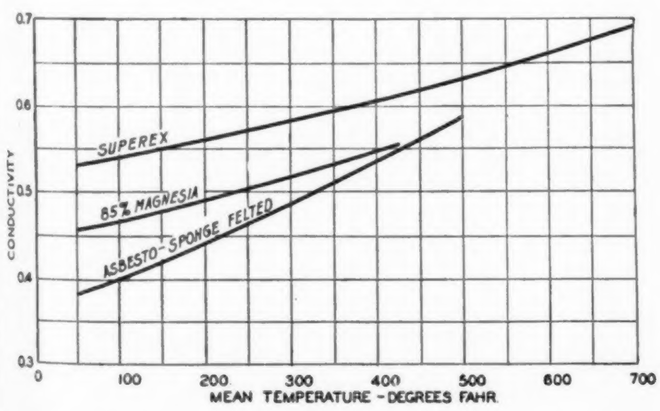


FIG. 4 CONDUCTIVITIES OF ASBESTO SPONGE FELTED, 85 PER CENT MAGNESIA AND SUPEREX

The scale of thickness for the second material is laid out uniformly on the right of a base line OO, which represents the dividing line between the two materials. The scale for the first material along a horizontal line representing room temperatures is laid out to the left of the base line, using a scale k_2/k_1 times that used for the first material, $OC = OA \times (k_2/k_1)$. However, this is the only line on which the mean temperatures for both materials are the same; therefore, to determine the proper scale at higher temperatures, the relative mean temperatures for several values of t_1 must be calculated and points located as at H. The distances OH and OA are inversely proportional to the conductivities of the respective materials at their mean temperatures.

It is evident that for combinations of thicknesses other than those for which the point H was located, the mean temperatures of the respective layers, and consequently the conductivities, will not be the same. However, in a given case both temperatures will be higher or both will be lower, so that variations are not cumulative, and in actual use errors due to the slight variations in these actual values are surprisingly small. For example, varying the proportions of the materials 100 per cent from those on which the chart is based, results in a difference of less than 0.5 per cent between actual values of conductivities and those at the mean temperatures as determined from the chart.

In order to use the chart, Fig. 3, for two materials and one surface resistance, R_s, locate point H at the point on the chart representing the thickness of the first material and temperature at its warmer face. Locate point A at the point representing the thickness of the second material and room temperature. Lay off distance $AD = R_s k_2$. Draw the straight line HD. The intersection of this line with the base line OO gives the temperature at the boundary between the two materials. The intersection with the line representing the outer surface of the second material gives the temperature of this surface.

Where more than two materials are involved, each material, other than the two for which the chart is laid out, is provided for in the solution in the same manner as was illustrated above for surface resistance. The chart applies equally well to insulation on pipes and on flat surfaces. The only difference is that in the case of pipe insulation, "equivalent thicknesses" [that is, values of $r_s \log_e (r_2/r_1)$, etc.] are used instead of actual thicknesses.

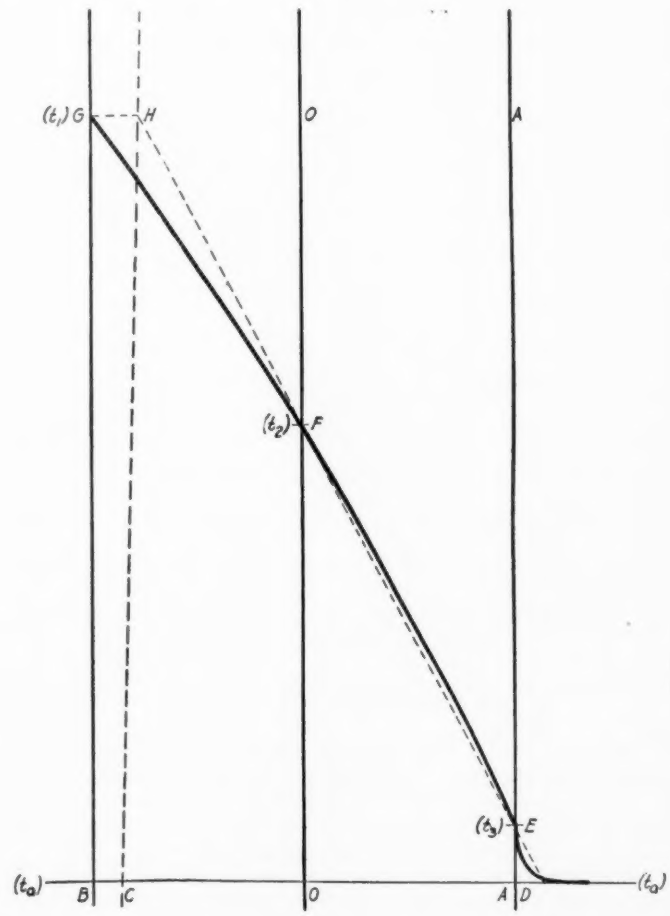


FIG. 5 TEMPERATURE GRADIENTS THROUGH SUPEREX AND 85 PER CENT MAGNESIA

The slope of the line HD is a function of rate of heat transfer from the outer surface to air. Since surface resistance is a variable which may, for a given set of conditions, be expressed as a function of the same rate of heat transfer, this relationship forms the basis for a method which long use has demonstrated to be highly convenient for eliminating the "cut and try" operation in connection with surface resistance. This method consists of

placing the base line of a protractor on the line *HD* and reading the surface resistance directly from suitable scales inscribed on the arc of the protractor.

The straight line *HD* on the chart, Fig. 3, illustrates the method of determining the temperature at the respective surfaces of 2-in.-thick Superex and 2-in.-thick 85 per cent Magnesia, where the temperature of the warmer surface is 800 deg. fahr., and the room temperature is 75 deg. fahr. The distance AD ($=R_sk_2$) may, for a given combination of materials and for still-air conditions, be taken as a constant without introducing appreciable error. For the combination of materials to which Fig. 3 applies this constant is 0.3 in. of the second material.

Concluding this phase of the discussion, it may be said that there is no urgent need for an extended program of research devoted to further determination of conductivities of commercial insulating materials in the moderate- and high-temperature fields. However, it cannot be too strongly urged that, in such results as are presented in the future, the mean temperature of the determination should be stated, and above all, the value reported as conductivity should actually be conductivity and not some odd combination of true conductivity with other, and extraneous, effects.

SURFACE EFFECTS

It has already been pointed out that the investigation of surface resistance offers a most fruitful field for further research. This does not mean that information on the subject is wholly lacking. In fact, sufficient data are available for the solution of most insulation problems with a highly satisfactory degree of accuracy. However, the deficiency of the work in this field (and the author makes no exception of his own earlier published results in this connection) is that results presented are overall coefficients, which make no provision for the separate effects of radiation and convection. One of these effects, radiation, is a function of the difference of the fourth powers of the absolute temperatures, while the other, convection, is generally considered to be a function of temperature difference. Therefore, while the results may be applied with assurance of accuracy to conditions closely approximating those under which they were obtained, they may not be extended very far beyond the range of actual experimentation.

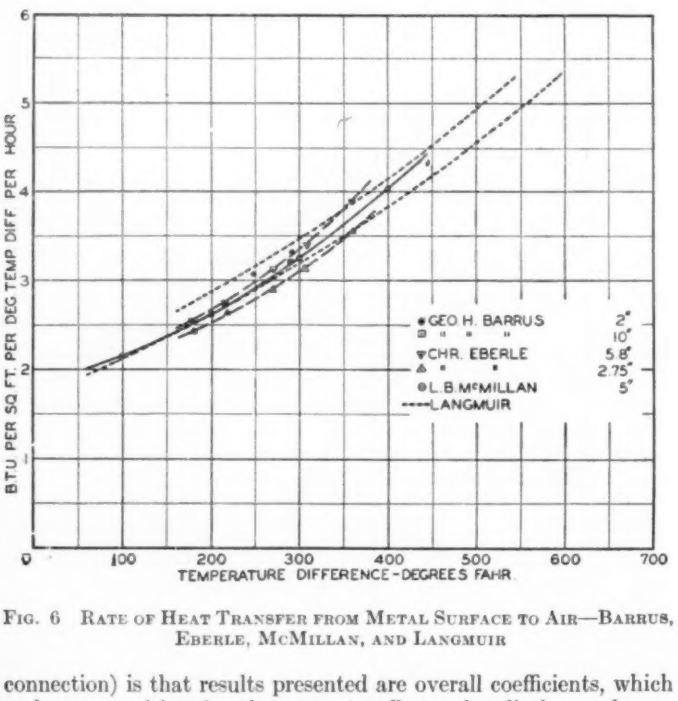


FIG. 6 RATE OF HEAT TRANSFER FROM METAL SURFACE TO AIR—BARRUS, EBERLE, MCMILLAN, AND LANGMUIR

The important effects of absolute temperature and of air velocity are too often neglected in this connection. It is generally conceded that the rates of heat transfer from cylindrical surfaces of small diameter, under still-air conditions, are greater than from those of larger diameter. Paulding's[8] deductions indicated a rather wide variation in this regard. Actual experiments charted by Heilman[9] showed a much smaller range of variation, and the composite chart,[10] Fig. 6, shows a close grouping of results for various diameters. In fact, it is apparent in all three charts that, except for the very small pipe sizes, smaller than 3 in., the differences due to pipe size are not large.

An interesting feature of Eberle's tests, shown in Fig. 6, is that the pipe of smaller diameter is shown to have the lower rates of loss. However, the air temperature, and consequently the absolute temperatures of both the pipe and its surroundings, were higher in the series of tests on the larger pipe. This undoubtedly accounts in a large measure for the peculiarity of the results.

As will be shown later, a relatively low air velocity will effect a relatively large increase in heat transfer from a surface. It is evident, therefore, that the effects of absolute temperature and of air velocity may completely overshadow the effect of pipe size. All results on bare-surface losses are to be considered as fairly convenient approximations which will serve until more scientifically complete data are available.

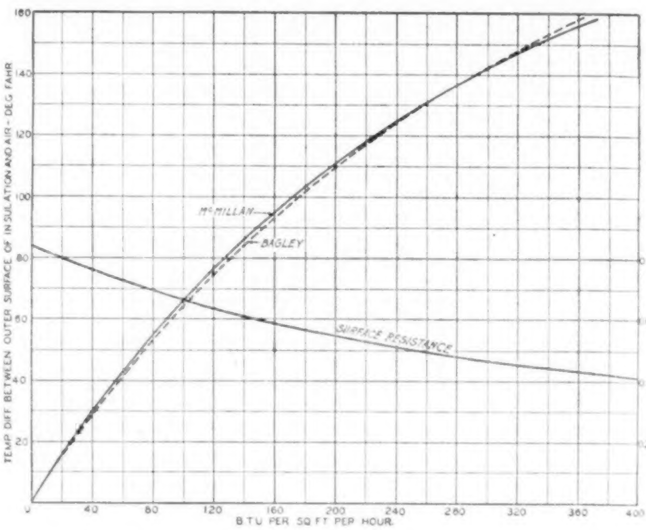


FIG. 7 RATES OF HEAT TRANSFER FROM CANVAS-COVERED INSULATION SURFACES TO AIR

The existing information on rates of heat transfer from insulation surfaces to surrounding air is in much the same state as that outlined above for bare surfaces. Fig. 7 shows results of experiments by the author[11] and by Bagley.[12] For the relationship between temperature difference, surface to air, $t_s - t_a$, diameter D, and rate of heat transfer from surface of insulation to surrounding air, h, Heilman[13] gives the equation

$$t_s - t_a = \frac{272.5h}{h + \dfrac{564}{D^{0.19}}} \qquad [12]$$

However, this equation is admittedly empirical and may not be used for diameters much beyond the range of his experiments. Where the surface resistance is relatively a small part of the total resistance, as it always is in the case of effectively insulated surfaces, the use of any one of these three methods permits the calculation of total rate of heat transfer to an accuracy of about 1 to 2 per cent, which is as exact as the conductivity values themselves, but even at that the use of these approximations must sooner or later give way to the use of more scientifically accurate data. At that time, charts very much like those now in use will be required for specific conditions, but that will be in the nature

[8] Practical Laws and Data on the Condensation of Steam in Covered and Bare Pipes. Published by D. Van Nostrand Co., New York, 1904.

[9] Trans. A.S.M.E., vol. 44, p. 301.

[10] G. H. Barrus, Trans. A.S.M.E., vol. 23 (1902), p. 791.
Chr. Eberle, Mit. über Forschungsarbeiten, Verein Deutscher Ing., heft 78.
L. B. McMillan, Trans. A.S.M.E., vol. 37 (1915), p. 941.
Langmuir, calculated from Equations [13] and [14].

[11] Trans. A.S.M.E., vol. 37 (1915), p. 956.

[12] Ibid., vol. 40 (1918), p. 675.

[13] Ibid., vol. 44 (1922), p. 308.

of particularizing from the general instead of generalizing from the particular, which is the tendency of present methods.

Effect of Air Velocity on Heat Transfer from Surface to Air. The principal need for more complete data on surface losses is that, until these are accurately expressed in terms of their component parts, *radiation* and *convection*, and until the effect of air velocity on the latter has been accurately determined, no satisfactory statement of the effect of air velocity on heat losses from surfaces may be obtained. The work of Langmuir[14] is outstanding in this connection. For radiation he uses the Stefan-Boltzmann equation, which, in engineering units, may be expressed as

$$W_R = 0.178E\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right] \qquad [13]$$

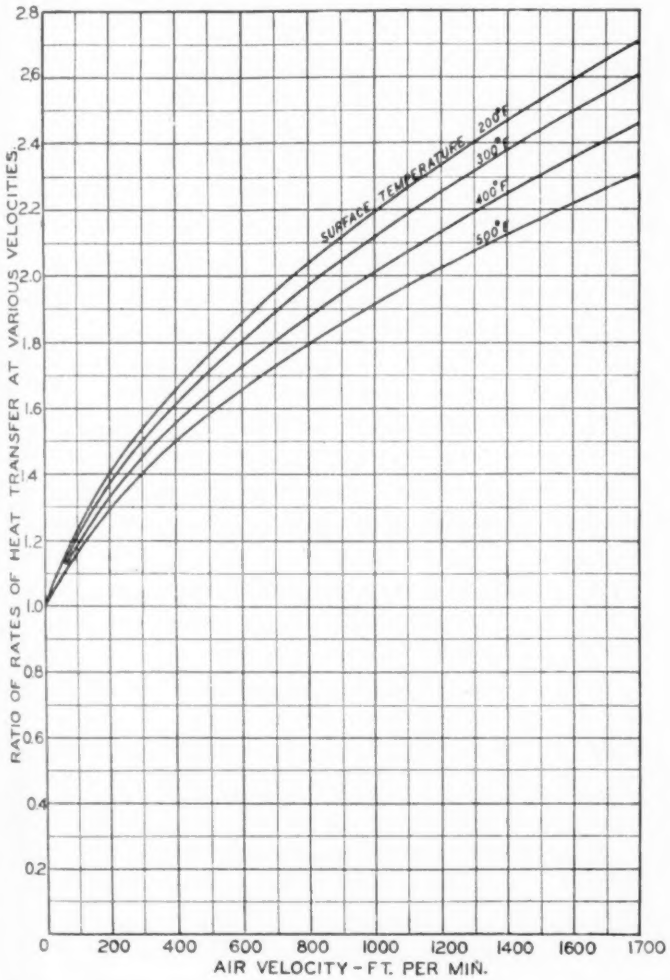


FIG. 8 RELATIVE RATES OF HEAT TRANSFER AT VARIOUS AIR VELOCITIES, BASED ON LANGMUIR'S EQUATIONS

(Rate of heat transfer under still-air conditions considered as unity.)

and for convection, he has developed the equation, which for still air under average conditions may be expressed as

$$W_C = 0.296\,(T_1 - T_2)^{5/4} \qquad [14]$$

The total rate of heat transfer is represented by the sum of these. He shows that convection is increased by air circulation, according to the equation

$$W_{CV} = W_C\sqrt{\frac{V + 68.9}{68.9}} \qquad [15]$$

The increases in heat transfer due to air velocity calculated from these equations, at various surface temperatures, and with an air temperature of 80 deg. fahr., are shown in Fig. 8. The actual rates of heat transfer, under the same conditions, are shown in Fig. 9.

In the above equation, W_R and W_C represent, respectively, the rates of heat transfer by radiation and by convection under still-air conditions. W_{CV} represents rate of heat transfer by convection at any air velocity. All are expressed in B.t.u. per square foot per hour. E is the emissivity coefficient, which for black-body conditions is unity. T_1 and T_a represent the absolute temperatures of the hot surface and of air, respectively, and T_2 represents the absolute temperature of surrounding objects to which heat is radiating. V represents the velocity of air flowing over the surface, expressed in feet per minute.

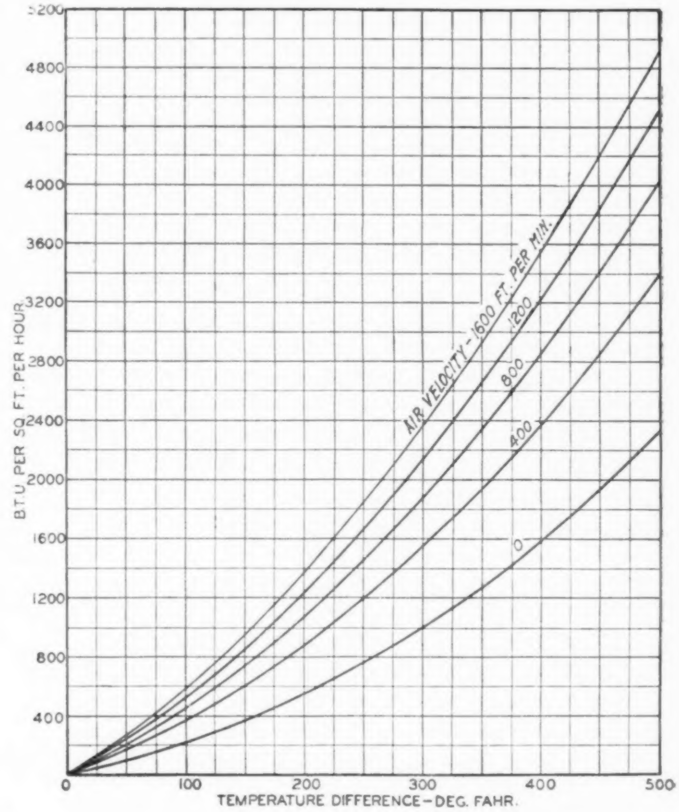


FIG. 9 EFFECT OF AIR VELOCITY ON RATES OF HEAT TRANSFER FROM SURFACES OF VARIOUS TEMPERATURES

(Air temperatures 80 deg. fahr.)

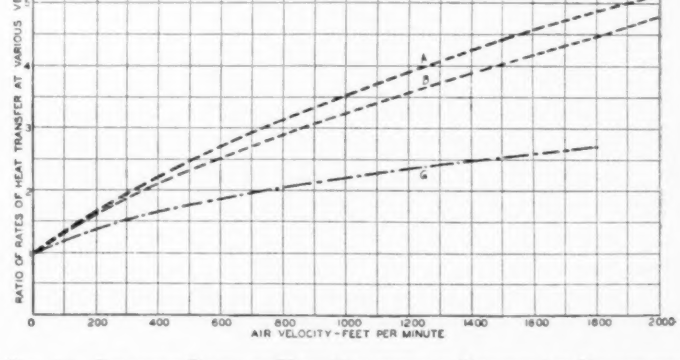


FIG. 10 RELATIVE RATIO OF HEAT TRANSFER AT VARIOUS AIR VELOCITIES AS SHOWN BY DIFFERENT INVESTIGATORS

(Rate of heat transfer under still-air conditions considered as unity.)[15]

[14] Trans. Am. Electrochem. Soc., vol. 23.

[15] A—T. S. Taylor, Trans. A.S.M.E., vol. 42 (1920), p. 243 (surface temperature, 113 deg. fahr.).

B—T. S. Taylor, Trans. A.S.M.E., vol. 42 (1920), p. 243 (surface temperature, 131 deg. fahr.).

G—Langmuir (Equations [13], [14], and [15]). (Surface temperature, 200 deg. fahr.; air temperature, 80 deg. fahr.)

While Langmuir's analysis of the problem is very convincing, it is probable that the effect of air velocity is greater than he has shown. See Fig. 10. Many tests by other investigators have shown increases more than double those given by Langmuir's equations. The results given by T. S. Taylor are of particular interest, since he shows that the angle of incidence of the air stream on the surface has a marked effect on the rate of heat transfer. It is not difficult to ascribe highly probable reasons for many of the most glaring disagreements in the various results from various sources. The differences between effects of streamline and turbulent flow and the failure to define, with reference to the surface, the point at which velocity was measured are outstanding possibilities in this connection.

Effect of Air Velocity on Heat Transfer Through Insulation. In the case of well-insulated surfaces the increases in heat losses due to air velocity are very small as compared to the increases just shown for bare surfaces. This is due to the fact that air flowing over the surface of the insulation can increase only the rate of heat transfer from surface to air and cannot change the internal resistance to heat flow inherent in the insulation itself. The effect of the air circulation, therefore, is to cool the surface of the insulation to a temperature lower than it would have under still-air conditions, thereby increasing the temperature drop through the

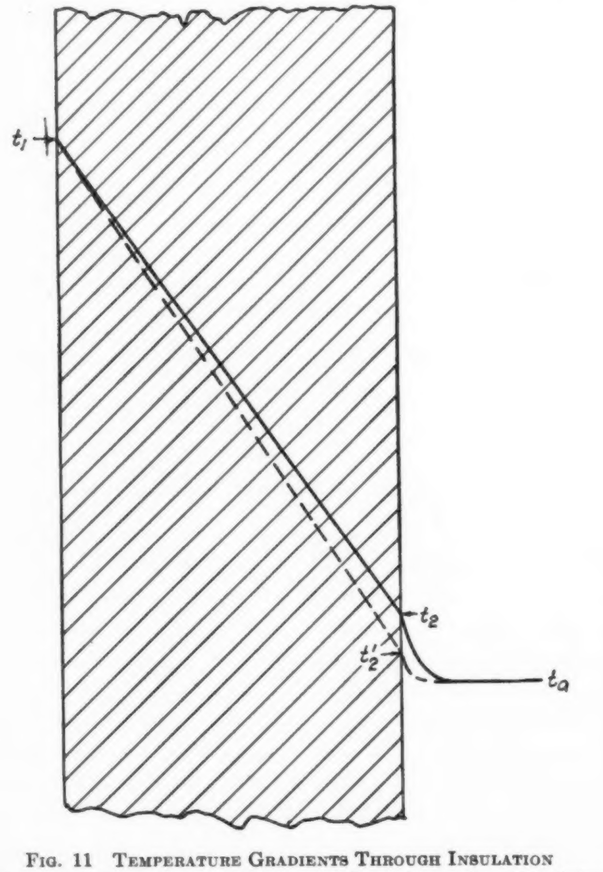


FIG. 11 TEMPERATURE GRADIENTS THROUGH INSULATION
(The dotted curve represents temperature gradient when surface of insulation is subjected to air circulation.)

insulation. This is illustrated in Fig. 11 by the decrease in temperature from t_2 to t'_2. Since the heat transfer in a given case is proportional to the temperature gradient, it is obvious that the heat flow will be greater when the temperature difference is $t_1 - t'_2$ than when it is $t_1 - t_2$.

In the case of surfaces located out of doors, the combined effect of wind and rain may bring the surface temperature of the insulation practically down to the air temperature, yet even in this extreme case the increase in heat loss through the insulation is not as great as might be expected. This is illustrated by the following example, based on a flat surface insulated with 2-in.-thick material, having a conductivity of 0.5 B.t.u. per sq. ft., per deg. temperature difference per 1 in. thickness, per hr., and a rate of heat transfer from its surface to air under still-air conditions of 1.8 B.t.u. per sq. ft. per deg. temperature difference per hr.[16]

Internal resistance of insulation = 2/0.5 = 4.0
Surface resistance = 1/1.8 = 0.556
Total resistance = 4.556
Rate of heat transfer = 1/4.556 = 0.22 B.t.u. per sq. ft. per deg. temperature difference per hr.

If the surface resistance were completely eliminated, due to the cooling action of wind and rain, the internal resistance of 4.0 would still remain, and the rate of heat transfer would be 1/4.0 = 0.25 B.t.u. per sq. ft. per deg. temperature difference per hr. There-

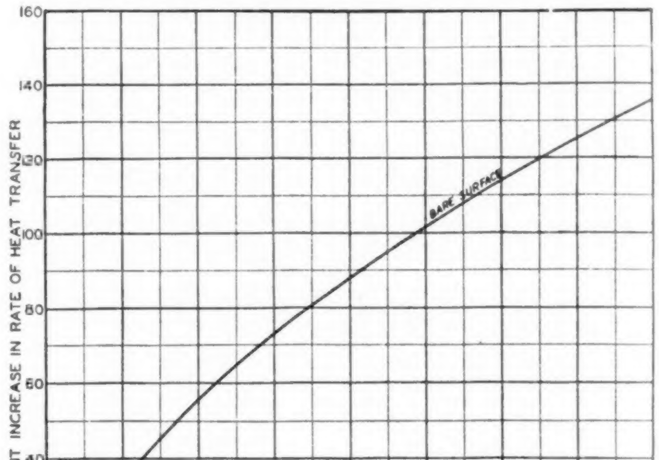


FIG. 12 INCREASE IN HEAT LOSSES DUE TO AIR CIRCULATION

fore the maximum increase in loss due to wind and rain would be

$$\frac{0.25 - 0.22}{0.22} = 13.6 \text{ per cent.}$$

In like manner it may be shown that the maximum increase for 1 in. thickness of the same material under the same conditions is 27.9 per cent and, in the case of 3 in. thickness, 9.2 per cent. It is therefore apparent that the thicker or the more efficient an insulation is, the less its rate of heat transfer will be affected by air circulation.

Fig. 12 shows graphically the relative increases in rates of heat transfer, due to air circulation, in the case of a bare surface maintained at 400 deg. fahr., and the same surface insulated with 1 in. and 2 in. thickness of an insulation with a conductivity of 0.48 B.t.u. per sq. ft., per deg. temperature difference per 1 in. thickness, per hour. In these curves, the effect of air velocity on rate of heat transfer from surface to air is based on Langmuir's equations.

All of the above discussion as to effect of air circulation on losses through insulation is based on flow of air over the surface of the insulation, and applies to cases where the insulation is tightly sealed. If the condition of the insulation is such that the air may circulate through cracks and crevices in the insulation, the increases may be far greater than those given above. Therefore it is essential that all insulation be sealed as tightly as possible; and this is most particularly true of insulation located out of doors.

Surface Temperature Not a Satisfactory Measure of Heat Transfer. The lack of a simple means to measure approximately the amount of heat loss from surfaces has naturally led to a widespread feeling that the degree of effectiveness of insulation may be estimated by the surface temperature. Probably no other conception in con-

[16] It should be noted that the factor 1.8 B.t.u. is not a constant for all cases, but is one of the stated conditions for this particular example.

nection with heat transfer is so generally misused as this one. Surface temperature considered alone, without reference to temperature of surroundings, is *absolutely no measure of the rate of heat transfer*. A surface at 150 deg. fahr. in a confined space exposed to air at 150 deg. fahr. may be losing no heat at all, whereas a surface at 100 deg. fahr. exposed to air at a temperature of 50 deg. fahr. is losing heat in very considerable quantities.

Measuring the difference between the surface temperature and the air temperature is a little better, but not much, unless all other conditions are identical—which they rarely are. It is easily

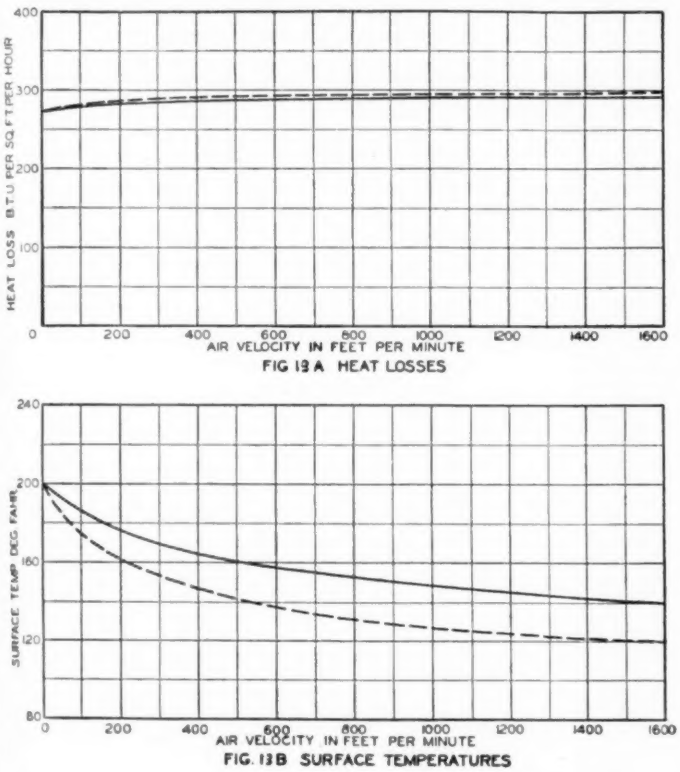


Fig. 13 Effect of Air Velocity on Heat Losses and on Surface Temperatures of Insulation

possible for the losses to vary over a range of several hundred per cent at the same temperature difference, depending on the air velocity to which the surface may be exposed. Nor is it necessary for that velocity to be very high in order to render either surface temperature or temperature difference, surface to air, entirely valueless as an indication of heat loss.

Air circulation over the surface of insulation increases the rate of heat transfer from the surface and, as illustrated in Fig. 11, this tends to cool its surface and increase the total rate of heat transfer. Therefore, *with lower surface temperature, more heat is being transmitted.* This fact is illustrated more forcibly in Fig. 8, where it may be seen that the rate of heat transfer from a surface 100 deg. fahr. above air temperature and exposed to air circulating at a velocity of 400 ft. per min. (approximately 4.5 miles per hour) is greater than for a surface 150 deg. fahr. above air temperature but exposed only to still air.

Reference to Fig. 13 illustrates still more clearly why surface temperatures do not give a reliable measure of heat transfer through insulation. The solid-line curves are based on the factors given in Fig. 8, while the dotted-line curves illustrate conditions which would exist if the increases in surface transmission rate due to air circulation were of the order of the higher values shown in Fig. 10. It is apparent that the higher rates of increase of surface losses would have little effect on the total rate of heat transfer, while surface temperatures would be still further reduced.

Air circulation is not the only cause of unreliability of surface temperature as a measure of heat loss. Exposure of the surface to other nearby hot or cold surfaces, and the nature of the surface itself, may have almost if not quite as noticeable effects on surface temperatures. A bright, polished surface may be losing heat at a rate not much over half as great as that from a dull surface and yet have a higher surface temperature.

While these variables will have relatively little effect on the total heat transmitted by the insulation, they may have entirely disproportionate effects on surface temperatures.

Economic Data

Perhaps the most valuable use for accurate data on heat transfer in connection with insulation is in the calculation of the thickness of insulation required under various conditions for most economical results. There have been many contributions to the literature on this subject, but most of the methods presented have been graphical. A notable exception is P. Nicholls' contribution[17] on the Economic Thickness of Insulation in the Refrigerating Field. However, long before that paper was presented, the author had been using in his own work a rational analytical method for insulation on flat surfaces, and has just recently extended this to apply to pipe surfaces.

Referring to Fig. 14, as the thickness of insulation is increased the cost of heat lost per year (m) is decreased, but the cost per year of insulation (n, first cost multiplied by per cent fixed charges) is increased. Therefore, the thickness at which the sum of these two costs is a minimum is obviously the most economical.

For flat surfaces this may be determined from the equation

$$x = \sqrt{\frac{ak}{b}} - Rk \qquad [16]$$

in which x is the most economical thickness, k is the conductivity,

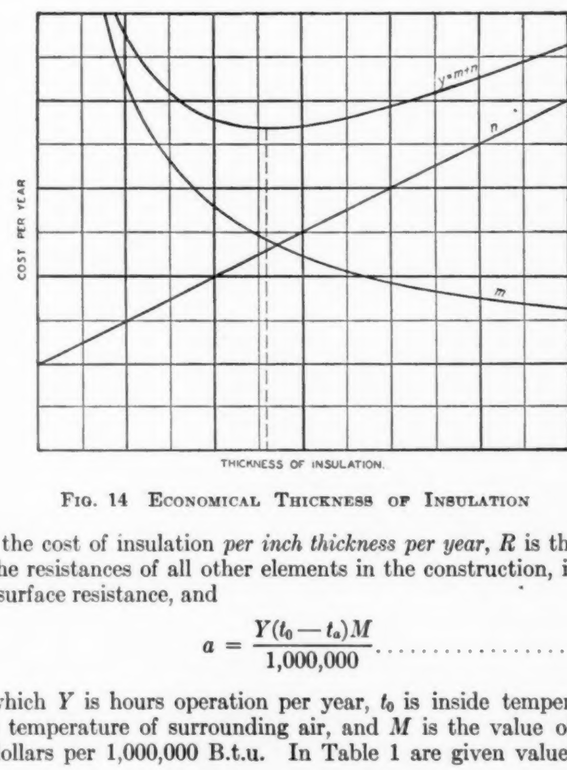


Fig. 14 Economical Thickness of Insulation

b is the cost of insulation *per inch thickness per year*, R is the sum of the resistances of all other elements in the construction, including surface resistance, and

$$a = \frac{Y(t_0 - t_a)M}{1{,}000{,}000} \qquad [17]$$

in which Y is hours operation per year, t_0 is inside temperature, t_a is temperature of surrounding air, and M is the value of heat in dollars per 1,000,000 B.t.u. In Table 1 are given values of a

TABLE 1 VALUES OF a

Temp. diff., deg. fahr.	Value of heat in dollars per million available B.t.u.									
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
100	0.088	0.175	0.263	0.350	0.438	0.526	0.613	0.701	0.788	0.876
200	0.175	0.350	0.526	0.701	0.876	1.051	1.226	1.402	1.577	1.752
300	0.263	0.526	0.788	1.051	1.314	1.577	1.840	2.102	2.365	2.628
400	0.350	0.701	1.051	1.402	1.752	2.102	2.453	2.803	3.154	3.504
500	0.438	0.876	1.314	1.752	2.190	2.628	3.066	3.504	3.942	4.380
600	0.526	1.051	1.577	2.102	2.628	3.154	3.679	4.205	4.730	5.256
700	0.613	1.226	1.840	2.453	3.066	3.679	4.292	4.906	5.519	6.132
800	0.701	1.402	2.102	2.803	3.504	4.205	4.906	5.606	6.307	7.008
900	0.788	1.577	2.365	3.154	3.942	4.730	5.519	6.307	7.096	7.884
1000	0.876	1.752	2.628	3.504	4.380	5.256	6.132	7.008	7.884	8.760

for various temperature differences, various values of heat, and 8760 hours per year. (See Appendix 4 to complete paper for derivation of Equation [16].)

[17] *Refrigerating Engineering*, Nov., 1922, p. 152.

Equation [16] applies to combinations of any number of materials, the resistance of all but one being provided for in the term R. The physical explanation of the situation is that the value of the term $\sqrt{ak/b}$ gives the thickness of the one material which would be required if there were no other insulating value in the construction than that offered by the material itself. If only one material is involved, the only deduction required is that for surface resistance. The term R_sk is then the thickness of material with conductivity k which has the same resistance as the surface resistance. In like manner, deductions are made for the insulating values of other elements already present in the construction. If it is desired to increase the thickness of the first layer for some reason, as for example to reduce the temperature to which the second layer is subjected, the solution is very simple. The value of the term $\sqrt{ak/b}$ does not change, but the value of R is increased and the thickness of the outer layer correspondingly decreased.

In the case of pipe surfaces, the equation for economical thickness is not quite so simple, yet it is by no means as formidable as it appears at first sight. For one material the cost of which may be expressed by the equation[18]

$$\text{Cost per linear foot} = \frac{2\pi r_2 b}{12}(r_2 - r_1) + C \ldots\ldots [18]$$

$$\left(r_2 \log_e \frac{r_2}{r_1} + R_s k\right)\sqrt{\frac{2r_2 - r_1}{r_2 - R_s k}} = \sqrt{\frac{ak}{b}} \ldots\ldots [19]$$

All terms in these equations have previously been defined. The derivation of Equation [19] is given in Appendix 5.

Recognizing that the first term within the parenthesis is equiva-

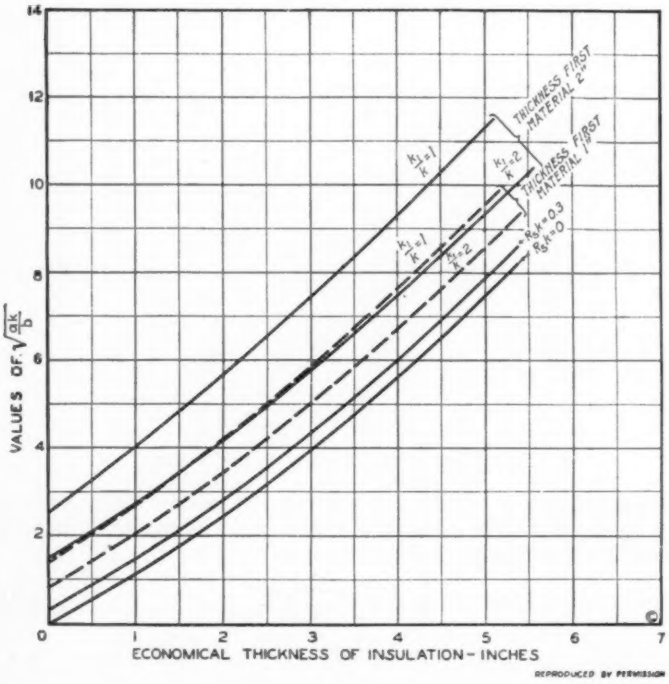


Fig. 15 Economical Thickness of Insulation on Cylindrical Surface 16 In. in Diameter

lent thickness, the close similarity to Equation [16] is at once apparent since Equation [16] may be written for one material

$$x + R_s k = \sqrt{\frac{ak}{b}}$$

Before proceeding with the solution of Equation [19], the equation for economical thickness of the outer layer of insulation over one or more layers of materials having different conductivities will be written, since the same charts may be used for the solution of equations involving all such combinations. This equation, given below, is written for a combination of two materials, but for more than two the equation is of exactly the same form. The only difference will be the addition of other terms like the second term inside the brackets and the substitution of appropriate values of r where r_s appears in the equation.

$$\left[r_s \log_e \frac{r_s}{r_2} + \frac{r_s}{r_1}\left(\frac{r_1 \log_e \frac{r_2}{r_1}}{k_1}\right)k + R_s k\right]\sqrt{\frac{2r_s - r_2}{r_s - R_s k}} = \sqrt{\frac{ak}{b}} \ldots [20]$$

In this equation all terms have been previously defined. Its derivation is given in Appendix 6, to the complete paper.

Fig. 16 Economical Thickness of Insulation on Flat and Curved Surfaces. R_sk = 0.3 In.

The solution of Equation [20] for 16-in. pipe is illustrated in Fig. 15. a, k, and b are established by the conditions of the problem. Knowing the value of $\sqrt{ak/b}$ the economical thickness may be read directly from the chart. For example if $\sqrt{ak/b} = 4.0$, and if no surface resistance is to be considered, the economical thickness is 3.03 in. If R_sk = 0.3 in. the economical thickness is 2.80 in. If there is a first layer of material 1 in. thick, and if the conductivity of that layer is 2.0 times that of the second layer (and R_sk = 0.3), the economical thickness of the second layer is 2.38 in. For intermediate values interpolations may be made. Naturally the thickness chosen would be the commercially available thickness nearest the thickness found on the chart.

The solution is graphical, it is true, and it may be asked why not then make a graphical solution in the first place by plotting the sum of the losses per year and costs per year for a number of thicknesses and taking the low point as the economical thickness. The answer is that each solution by that or other equivalent methods requires a number of calculations, the plotting of a curve, and the location of the minimum point or the point where tangents are parallel, all of which is tedious, and the last step of which is

[18] The so-called "Standard List Prices" of sectional pipe insulation are in reasonably close agreement with Equation [18] for thicknesses greater than 1 in. Prices of cork pipe covering follow no regular law. Therefore these Equations, [18], [19] and [20], do not apply to cork.

likely to be highly inaccurate, while the solution described above requires but a few moments once the charts have been prepared.

The chart illustrated in Fig. 16 is applicable to the instant solution of most problems where a single material is involved. It is based on R_sk = 0.3 in., which is fairly representative of good insulating materials under average still-air conditions. Even if R_sk for the given case differs considerably from the value of 0.3 in., the change in economical thickness will usually be so small as to be practically negligible. However, if somewhat greater accuracy is required, correction may be made by adding to the thickness given by the chart the amount in inches by which R_sk is less than 0.3 in., or subtracting from the thickness the amount by which R_sk exceeds 0.3 in. Where absolute accuracy is required and where combinations of materials are involved, it is necessary to use a chart such as Fig. 15 for each pipe size.

Conclusions

It has been shown that the phase of heat transfer in which further research is most urgently needed is in the whole broad field of surface effects. In this connection it is not amiss to suggest that where the pure scientist misses the mark is that he probably feels an entirely justifiable satisfaction in being able to set up an equation which provides adequately for the effect of every variable, and the more complex the equation the more keen the satisfaction; but he fails to extend his analysis a step further to the point which makes the application of the equation to actual cases conveniently useful.

This illustrates the necessity of a meeting of the minds of scientists and engineers. Usually the engineer has neither the time nor the inclination to delve into the intricacies of the underlying phenomena to an extent which enables him to establish general laws. He is too much inclined to be satisfied with the apparent relationships of the more prominent variables and to express them in an empirical fashion. Yet he has a very clear idea of the form in which the results should be expressed in order that they be most practically useful.

Bringing these extreme points of view into accord would be most profitable. For example, relatively few engineers would be much interested in having to use, for the solution of every problem involving heat transfer from surfaces, equations of the type of Equations [13], [14], and [15], to say nothing of the general equation for convection of which [14] is only a special case. On the other hand, he will use and appreciate the same data presented in the form illustrated by Fig. 9. It is true that the use of the data in such form is limited to the conditions on which the charts are based, but if the limitations are clearly stated, they will generally be heeded.

It is highly probable that with the mass of scientific data available on various phases of the subject, the combined efforts of a group of scientists and engineers could be depended upon to iron out existing contradictions and discrepancies and put the state of knowledge of heat transfer from surfaces to air in very satisfactory shape, with a minimum of actual laboratory work. There is an obvious need for such further investigations dealing with fundamentals. In addition to the effects of air velocity, the effects of shape, extent, position, and nature of the surface on the rate of heat transfer should be investigated and the results put in a form for convenient use.

It has been pointed out that the true significance of conductivity is not understood by many who have contributed and are contributing to the literature. So long as authors who are classed as authorities use the term *conductivity* loosely to apply to two or more distinctly different units, what hope is there that the layman, or even the experienced engineer who has only occasional contact with heat-transfer problems, will not be confused? It is usually possible for the specialist in heat transfer to sense immediately whether the term conductivity is used in its true significance or not. If he finds that the term is used as an overall unit, including the effects of one or more conductivities and various and sundry surface, shape, and thickness effects, his respect for the article in question is likely to be in inverse proportion to the number of effects other than true conductivity which are included in the so-called "conductivity" items. It is not difficult to find abundant examples in the literature illustrating the fact that if the elementary principles of heat transfer were more thoroughly understood the state of the literature on this subject would be greatly benefited thereby.

If this paper makes any considerable headway in clarifying the meaning and use of the term conductivity, and in emphasizing the importance of a thorough understanding of surface resistance, it will have been worth the effort and more. To those who have made a lifetime study of heat transfer, the treatment of the subject in this paper will appear for the most part elementary in the extreme. The presentation is elementary, and that it is such is intentional. The literature of heat transfer is expanding rapidly and it is essential that, if the current literature is to add anything of material value to the fund of knowledge on the subject, it must be based on the sound foundation of fundamental facts. It is useless to attack the more difficult problems without a clear understanding of these basic principles.

The Influence of Elasticity on Gear-Tooth Loads

Progress Report No. 6 of the A.S.M.E. Special Research Committee on Strength of Gear Teeth[1]

THIS progress report gives the third of a series of studies of the influence of elasticity on gear-tooth loads. Progress Report No. 4 gave a study of the influence of elasticity on perfect gears, and Progress Report No. 5 a study of the influence of errors on the acceleration loads, while this report will deal with impact loads on elastic materials.

III IMPACT LOADS

The following analysis of elastic impact was made by Carl G. Barth, who is now a member of the Special A.S.M.E. Research Committee on the strength of gears.

The following investigation of elastic impact would seem to have some bearing on the increment loads on gear teeth, for in some way an error of any kind in the shape or position of one or more teeth must produce an impact that puts an increased load on the teeth.

Referring to Fig. 1, which represents two instantaneous positions of two elastic bodies in impact, let

V_c = common velocity of the two bodies after the initial impact has taken place

F = final compressive force between the two masses after the initial impact

x_1 = corresponding maximum elastic yield of m_1

x_2 = corresponding maximum elastic yield of m_2

[1] The personnel of the A.S.M.E. Special Research Committee on the Strength of Gear Teeth is as follows:

Wilfred Lewis, *Chairman*, President, Tabor Manufacturing Company, 6225 Tacony Street, Philadelphia, Pa.

Carl G. Barth, 420 Whitney Avenue, New Haven, Conn.

Earle Buckingham, Professor, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Ralph E. Flanders, Manager, Jones & Lamson Machine Company, Springfield, Vt.

Arthur M. Greene, Jr., Dean, School of Engineering, Princeton University, Princeton, N. J.

Clarence W. Ham, Professor of Machine Design, University of Illinois, 115 Transportation Building, Urbana, Ill.

Charles H. Logue, *Secretary*, Consulting Engineer, 123 Clarke Street, Syracuse, N. Y.

Fred E. McMullen, Manager Cutter Department, The Gleason Works, Rochester, N. Y.

Edward W. Miller, Chief Engineer, Fellows Gear Shaper Company, Springfield, Vt.

Ernest Wildhaber, 379 Alexander Street, Rochester, N. Y.

z_1, z_2 = elasticity form factors of m_1 and m_2
E_1, E_2 = moduli of elasticity of m_1 and m_2.

We then have

$$F = z_1E_1x_1 = z_2E_2x_2$$

whence

$$x_1 = \frac{F}{z_1E_1} \quad \text{and} \quad x_2 = \frac{F}{z_1E_1}$$

and

$$x_1 + x_2 = F\left(\frac{z_1E_1 + z_2E_2}{z_1E_1 \times z_2E_2}\right) \qquad [1]$$

The total energy, which is all kinetic energy, at the beginning of impact, is equal to

$$\frac{m_1V_1^2 + m_2V_2^2}{2}$$

The total kinetic energy at the instant of maximum compression is equal to

$$\frac{(m_1 + m_2)V_c^2}{2}$$

$$V_c = \frac{m_1V_1 + m_2V_2}{m_1 + m_2}$$

and

$$V_c^2 = \frac{m_1^2V_1^2 + 2m_1m_2V_1V_2 + m_2^2V_2^2}{(m_1 + m_2)^2}$$

Substituting this value of V_c^2, the total kinetic energy at the instant of maximum compression is

$$\frac{m_1^2V_1^2 + 2m_1m_2V_1V_2 + m_2^2V_2^2}{2(m_1 + m_2)}$$

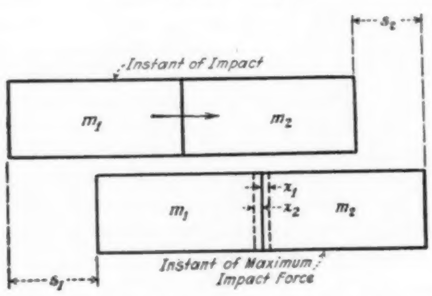


Fig. 1 Representation of Two Instantaneous Positions of Two Elastic Bodies in Impact

The loss of kinetic energy during impact is equal to the amount of potential energy stored in the compressed bodies, hence

$$\frac{F}{2}\left(x_1 + x_2\right) = \frac{m_1V_1^2 + m_2V_2^2}{2} - \frac{m_1^2V_1^2 + 2m_1m_2V_1V_2 + m_2^2V_2^2}{2(m_1 + m_2)}$$

or

$$F(x_1 + x_2) = \frac{m_1m_2(V_1 - V_2)^2}{m_1 + m_2}$$

Substituting the value of $(x_1 + x_2)$ from Equation [1] in the foregoing we have

$$F^2 = \frac{m_1m_2}{m_1 + m_2} \times \frac{z_1E_1z_2E_2}{z_1E_1 + z_2E_2} \times (V_1 - V_2)^2$$

whence

$$F = \sqrt{\frac{m_1m_2}{m_1 + m_2} \times \frac{z_1E_1z_2E_2}{z_1E_1 + z_2E_2}} \times (V_1 - V_2) \qquad [2]$$

Equation [2] gives the maximum force of impact when all of the energy is stored in the moving bodies. We shall now consider the conditions that exist when each of these masses is acted upon by an equal and opposed outside force f.

When a constant force f acts on the two bodies, some account must be taken of the work done by this force through the space in which these bodies travel while the impact is taking place. As before, the loss of kinetic energy during impact is equal to the amount of potential energy stored in the compressed bodies. This potential energy, however, is now equal to $(^1/_2F - f)\ (x_1 + x_2)$, whence

$$(F - 2f)\ (x_1 + x_2) = \frac{m_1m_2(V_1 - V_2)^2}{m_1 + m_2}$$

Substituting as before, we have

$$F^2\left(\frac{z_1E_1 + z_2E_2}{z_1E_1z_2E_2}\right) - 2fF\left(\frac{z_1E_1 + z_2E_2}{z_1E_1z_2E_2}\right) - \frac{m_1m_2(V_1 - V_2)^2}{m_1 + m_2} = 0$$

$$F = f + \sqrt{f^2 + \frac{z_1E_1z_2E_2}{z_1E_1 + z_2E_2} \times \frac{m_1m_2}{m_1 + m_2}\ (V_1 - V_2)^2} \qquad [3]$$

Referring now to Fig. 2, we shall consider the conditions when the two bodies are separated a distance k and then brought together

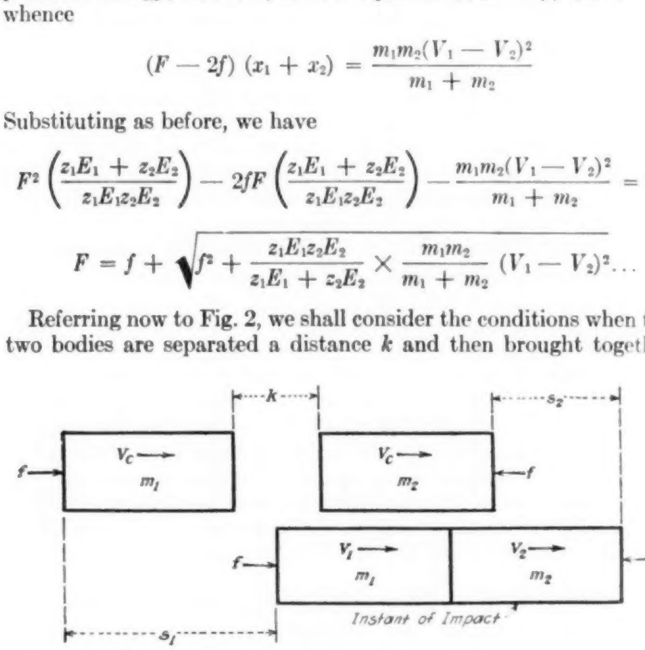


Fig. 2 Conditions When Two Bodies Are Separated a Distance k and Then Brought Together Again by Force f

again by the force f. At the instant of maximum separation, both bodies will be traveling at the same velocity. Then when

t = time for m_1 to overtake m_2
s_1 = space traveled by m_1
s_2 = space traveled by m_2

$$V_1 = V_c + at = V_c + \frac{ft}{m_1}$$

$$V_2 = V_c - at = V_c - \frac{ft}{m_2}$$

$$(V_1 - V_2) = \frac{m_1 + m_2}{m_1m_2} \times ft \qquad [4]$$

$$s_1 = \frac{V_c + V_1}{2}t$$

$$s_2 = \frac{V_c + V_2}{2}t$$

$$(s_1 - s_2) = k = {}^1/_2(V_1 - V_2)t$$

$$t = \frac{2k}{V_1 - V_2}$$

Substituting in Equation [4], we have

$$(V_1 - V_2)^2 = \frac{m_1 + m_2}{m_1m_2} \times 2kf \qquad [5]$$

Substituting this value of $(V_1 - V_2)^2$ in Equation [3], we have

$$F = f + \sqrt{f^2 + \frac{z_1E_1z_2E_2}{z_1E_1 + z_2E_2} \times 2kf} \qquad [6]$$

For a suddenly applied load, k would be equal to zero, and Equation [6] would give

$$F = 2f$$

For a static load, k would be minus and equal to one-half the static deformation of both of the bodies. Whence the value of k for a static load would be equal to

$$-\frac{f}{2} \times \frac{z_1E_1 + z_2E_2}{z_1E_1z_2E_2}$$

Equation [6] would then give for a static load $F = f$

Equation [6] thus seems to be a general equation for all conditions

of load—impact loads, suddenly applied loads, static loads, and any intermediate conditions of load. Equation [6] is of the same form as that derived by Merriman for impact loads on beams. Merriman discusses the use of a time factor to modify the value of the radical in this equation to make it apply to all cases. It would seem, however, that the use of a minus value for k when the bodies were partially compressed before the full load was released would be a more logical solution.

Applied to gear-tooth loads, we have several troublesome factors which make necessary the use of approximations. For one thing, the deformation of the tooth profiles is variable, depending upon the position on the tooth where the load is applied and also upon whether one or two pairs of teeth are carrying the load. These variables have been discussed in the previous studies and certain approximations have been tentatively selected for use in analyzing the load conditions. We shall therefore summarize these tentative relationships and introduce them into the solution of Equation [6].

We have first Equation [I-26] as follows:

$$d_t = f\left(\frac{z_1E_1 + z_2E_2}{z_1E_1z_2E_2}\right) \qquad [7]$$

Introducing this value into Equation [6], we have

$$F = f\left(1 + \sqrt{1 + \frac{2k}{d_t}}\right) \qquad [8]$$

For the elasticity form factor of gear teeth we have the approximation given by Equation [I-25] as follows:

$$z = \frac{1}{0.242/y + 7.25} \qquad [9]$$

where y = Lewis tooth-form factor. Table 1 gives the y and z factors for $14^1/_2$-deg., 20-deg. full-depth, and 20-deg. stub-tooth involute gears.

When a separation is caused by the acceleration load, we have

TABLE 1 TOOTH FORM AND ELASTICITY FORM FACTORS FOR $14^1/_2$-DEG., 20-DEG. FULL-DEPTH, AND 20-DEG. STUB-TOOTH INVOLUTE GEARS

Number of teeth	$14^1/_2$-deg. involute y	z	20-deg. full-depth tooth y	z	20-deg. stub-tooth y	z
12	0.067	0.09206	0.078	0.09659	0.099	0.10315
13	0.071	0.09382	0.083	0.09837	0.103	0.10417
14	0.075	0.09545	0.088	0.10000	0.108	0.10537
15	0.078	0.09659	0.092	0.10121	0.111	0.10604
16	0.081	0.09768	0.094	0.10179	0.115	0.10690
17	0.084	0.09871	0.096	0.10235	0.117	0.10731
18	0.086	0.09936	0.098	0.10289	0.120	0.10791
19	0.088	0.10000	0.100	0.10341	0.123	0.10849
20	0.090	0.10061	0.102	0.10392	0.125	0.10886
21	0.092	0.10121	0.104	0.10442	0.127	0.10922
23	0.094	0.10179	0.106	0.10490	0.130	0.10975
25	0.097 –	0.10262	0.108	0.10537	0.133	0.11026
27	0.099	0.10315	0.111	0.10604	0.136	0.11075
30	0.101	0.10367	0.114	0.10669	0.139	0.11122
34	0.104	0.10442	0.118	0.10752	0.142	0.11168
38	0.106	0.10490	0.122	0.10830	0.145	0.11212
43	0.108	0.10537	0.126	0.10904	0.147	0.11241
50	0.110	0.10582	0.130	0.10975	0.151	0.11291
60	0.113	0.10648	0.134	0.11042	0.154	0.11336
75	0.115	0.10690	0.138	0.11107	0.158	0.11387
100	0.117	0.10731	0.142	0.11168	0.161	0.11425
150	0.119	0.10772	0.146	0.11226	0.165	0.11472
300	0.122	0.10830	0.150	0.11282	0.170	0.11529
Rack	0.124	0.10868	0.154	0.11336	0.175	0.11584

the approximation given by Equation [II-13] for the value of k when but a single pair of teeth are in contact, as follows:

$$k = \frac{f_a}{f}e' - \left(\frac{f_a}{f}\right)^2\frac{d_t}{2} - d_t \qquad [10]$$

For the acceleration load f_a we have Equation [II-9] as follows:

$$f_a = \frac{f_1f_2}{f_1 + f_2} \qquad [11]$$

From Equation [II-7] we have

$$f_1 = 0.0025p\left(\frac{R_1 + R_2}{R_1R_2}\right)mV^2 \qquad [12]$$

From Equation [II-8]

$$f_2 = f\left(\frac{e'}{d_t} + 1\right) \qquad [13]$$

and Equation [II-10] as follows:

$$m = \frac{m_1m_2}{m_1 + m_2} \qquad [14]$$

where k = separation of gear-tooth profiles in inches
f_a = acceleration load
f = applied load
F = maximum impact load
e' = error on gear-tooth profiles in inches
d_t = static deformation at pitch line of gear tooth in inches
z = elasticity tooth-form factor
E = modulus of elasticity of material
p = circular pitch of gears in inches
R = pitch radius of gears in inches
m = effective mass at pitch line of gears
m_1 = effective mass of pinion at pitch line
m_2 = effective mass of gear at pitch line and
V = pitch-line velocity of gears in feet per minute.

Before the foregoing can be applied to the analysis of the test results, it is necessary to determine the influence of the rotating masses of the gear-testing machine on the effective masses of the test gears. There is a heavy solid pulley, for example, mounted on the pinion shaft. Due to the elasticity of the pinion shaft, only a part of this mass is effective at the pitch line of the pinion. The next step in these analyses of the influence of elasticity on gear-tooth loads is a study of the influence of the rotating masses. The next

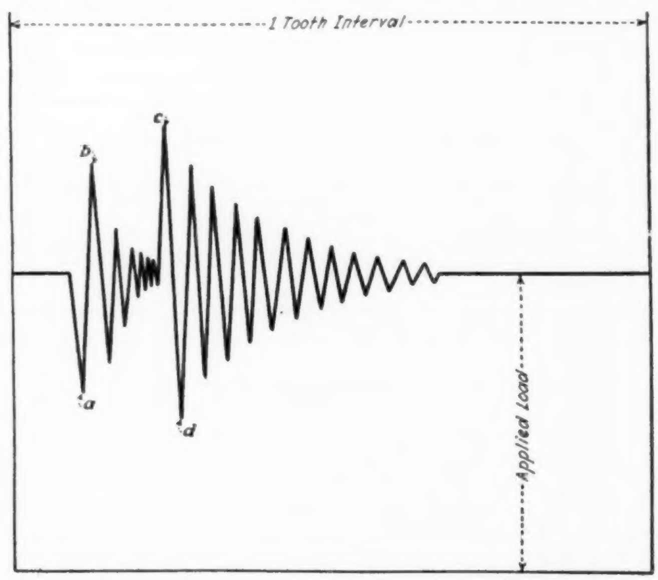


Fig. 3 Load Variations on Perfect Gear Teeth

report will give such an analysis together with data of the tests made to check this study.

We are now in a position, however, to visualize a little more clearly the character of gear-tooth loads. Even with perfect teeth, the load is not constant at all phases of the tooth mesh. Fig. 3 is a diagram of the variation in tooth load during the action of a single tooth interval.

When the contact changes from two pairs of teeth to but a single pair in contact the static deformation increases, which results in a reduced load as indicated at *a*. Of course, when the load is divided between two pairs of teeth, each pair is carrying only a part of the load. This change in the amount of deformation, however, tends to reduce the velocity of the revolving masses. As soon as the single pair of teeth has taken over the full load, any lost velocity must be restored in a very short space of time. This will result in an increased load as indicated at *b*, and this increased load will be carried by a single pair of teeth. This rapid change of load will set up vibrations, their period depending upon the natural period of the gear teeth. These vibrations will be damped by the applied load and the friction between the tooth profiles as well as by the internal friction in the material.

When a second pair of teeth come into contact again, the masses must be moved apart again the distance they have lost when chang-

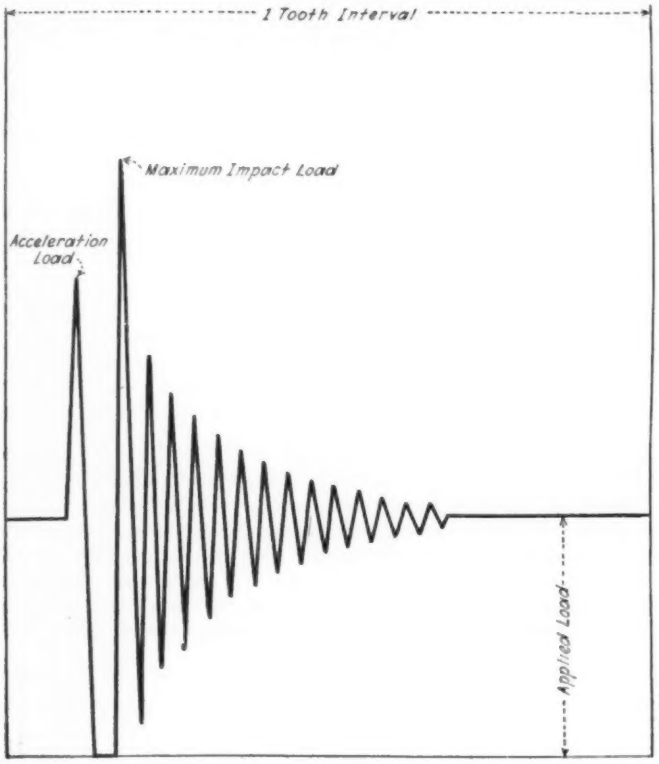


Fig. 4 Load Variations on Imperfect Gear Teeth

ing to contact with but a single pair. This results in an acceleration load, as indicated at *c*, together with similar reactions as before. Most of this acceleration load will be carried by the engaging pair of teeth, but the reactions would probably be shared by both pairs of teeth in contact.

When a positive error is present, whose extent is greater than the deformation of the material, one pair of teeth only will carry the load except as the contact shifts from one pair of teeth to the next pair. When the acceleration load caused by such an error is sufficient to cause the teeth to leave contact with each other, they will come together again with an impact, which would result in the load conditions indicated in Fig. 4. In this case the value of k, or the amount of separation, would be plus.

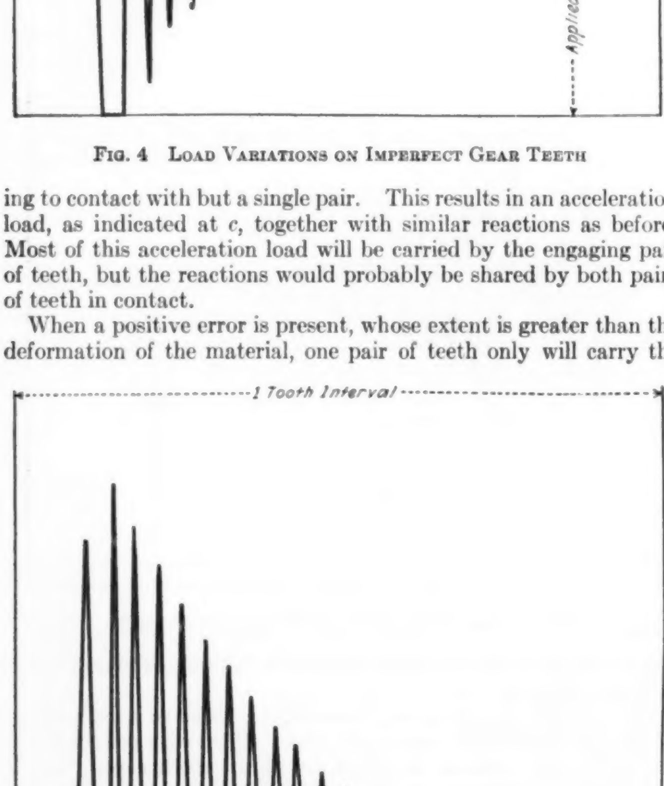


Fig. 5 Load Variations on Imperfect Gear Teeth

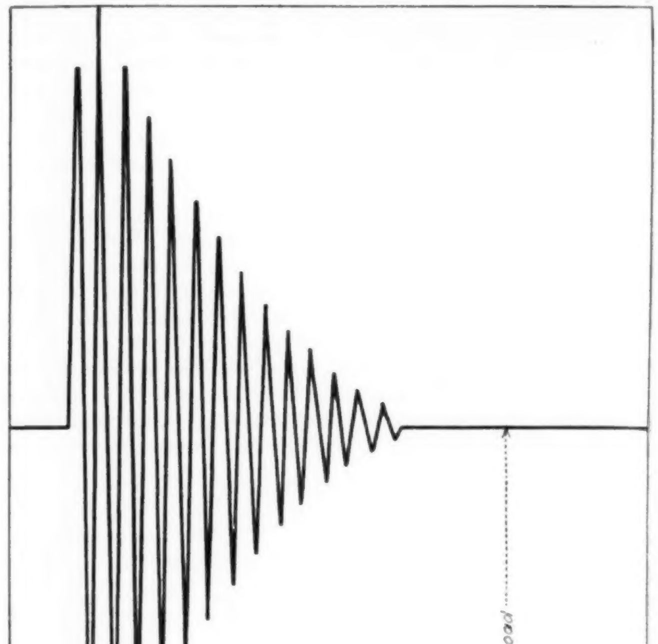


Fig. 6 Load Variations on Imperfect Gear Teeth

If the applied load on these same gears were increased so that the acceleration load resulted in a zero load for an instant, we should have the conditions shown in Fig. 5. In this case the maximum impact load would be double the applied load, and the value of k would be zero.

If the applied load were increased still further on these same gears, the acceleration load would not be sufficient to reduce the minimum instantaneous load to zero, and we should have the conditions indicated in Fig. 6. In this case the value of k would be minus and the maximum load would be less than double the applied load.

The critical load in all cases is the maximum one, and the purpose of these analyses is to attempt to establish some basis of checking the test results obtained on the Lewis gear-testing machine, and to determine from them the probable maximum tooth load.

In the early period of the oil business, oil wells varied in depth from 800 to 1800 ft. A 2000-ft. well was considered unusually deep. Today, wells 2000 ft. deep are considered shallow, and many wells now are 5000 ft. in depth. This increase in the depth of oil wells requires larger and heavier equipment for drilling, heavier materials used in the well, heavier pumping equipment, longer and heavier pumping rods, and greater power capacity for oil-well purposes. Gas engines are stated by Pat Shouvlin, in a paper presented before the American Petroleum Institute, to be the most economical and efficient for use for oil-well drilling and operation. In most cases, gas is so plentiful at the oil fields that it goes to waste, and hence, the only expense for gas-engine operation is the cost of maintenance, lubricating oil, depreciation, and labor.—*Machinery*, July, 1927, vol. 33, no. 11, p. 828.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Continuous Sheet Rolling

SINCE THE publication of the article on Recent Developments in the Rolling of Sheet Steel in MECHANICAL ENGINEERING, May, 1927, pp. 451–454, a series of articles have appeared in *The Iron Age* and *Iron Trade Review* describing various installations of the continuous process in this country. The purpose of the present symposium is to present briefly the main characteristic features of each of these installations in the expectation that those especially interested in the subject will go to the original articles for further detail.

COLUMBIA STEEL COMPANY

The original Columbia Steel Co. with the plant at Elyria, Ohio, has been engaged in the manufacture of cold-rolled strip steel since 1921. In the early part of 1926 it assumed control of the Forged Steel Wheel Co. at Butler, Pa. Foundations for the installation of the continuous sheet mill were started in May, 1926, and the initial lot was rolled November 25, 1926, which is considered to be a record in rolling-mill circles. Such quick work was possible only because of previous experience in a cognate line of manufacture.

Natural gas is found in abundant quantities in and around Butler and is used throughout the steel works and rolling-mill departments of the Columbia Steel Co. with the exception of the soaking pits. Under normal operation the plant uses daily about 13,000,000 cu. ft. Natural gas has the lowest sulphur content of any fuel used for heating or melting purposes. It is therefore an ideal fuel for melting open-hearth charges, as it admits of holding the sulphur content of the steel around 0.002 per cent. The gas pressure at the burner is approximately 2 lb. per sq. in. All open-hearth charges are melted from the cold state, approximately 5,000,000 B.t.u. being consumed per ton of steel melted.

All ingots are broken down to slab form on a 34-in. universal mill, which is equipped with a pair of vertical rolls arranged on each side of a pair of horizontal rolls. This particular mill will handle ingots from 3 to 10 tons and from 9 to 43 in. wide. The mill was formerly driven by a steam engine, but now by a 7000-hp. reversing motor.

When the ingot is reduced to the desired slab dimension, the section is taken from the universal mill by a run-out table which leads to a shear. Here the section is cut to desired lengths and is passed into stock or is loaded into special insulated cars so that a large part of the initial heat from the open-hearth and soaking-pit furnaces is retained when the steel subsequently is charged into the strip-sheet mill reheating furnaces. In this way the heating cost is kept to a minimum. Incidentally, the slabs are delivered with square edges, clean-cut ends, flat surfaces, and free from impurities.

The slab is next rolled in a four-stand 16-in. tandem hot mill. The housings are spaced on 22-ft. centers and contain four-high rolls. The top and bottom rolls known as the back-up rolls are mounted in roller bearings and operate by friction with the two working rolls between. The top roll is spring balanced. The working rolls are 16 in. in diameter and are made of chilled iron, while the back-up rolls are 32 in. in diameter and are made of steel. The gap between the working rolls is varied by a screw-down arrangement operated either by hand or motor. One revolution reduces the roll gap 0.005 in. Each pair of working rolls is driven individually by a 2000-hp. variable-speed motor.

Incidentally, the slab leaving the heating furnace has a temperature exceeding its upper critical point. By the time it arrives at stand No. 4 of the hot-mill train, the temperature of the steel is at its upper critical point. The steel at this temperature is in the austenitic state and is soft and ductile. Therefore with the proper amount of draft through the successive passes, the grain structure of the steel is refined by the mechanical action of the rolls and as the strip sheet leaves the last stand of the hot-mill train, its structure is refined and its surface smooth and free from scale.

The mill is capable of delivering sheets in a minimum thickness of 0.05 in., or 18 gage, with maximum widths of 36 in. and maximum length of 400 ft.

Stock which has to be cold rolled and coming from the hot mill is pickled, cleaned, sheared, and sent to the cold-rolled mill. Cold rolling imparts a highly polished surface to the steel and renders the structure dense and compact. The cold-roll set-up of the Columbia installation includes four stands of four-high rolls arranged in tandem with each set of rolls driven at various speeds. One of the prime requisites of cold rolling is to avoid vibration and chatter marks being imparted to the surface of the steel, and these irregularities largely are averted by transmitting power to the working rolls through herring-bone reduction gears. The rolls used in the cold mills are made of hardened steel, the dimensions of the working and back-up rolls being the same as in the hot mill. Likewise only the working rolls are driven, a 500-hp. motor being employed for each stand. Tension is imparted to the strip sheet between stands during the rolling process so as to eliminate or prevent the formation of buckles. This is accomplished by controlling the peripheral speed of the rolls by an automatic process.

One of the most interesting features of the Columbia plant is the continuous annealing. This cannot be described here, however, because of lack of space.

Before this particular installation was built few devices were available for stripping coils from reeling machines. This is probably explained by the fact that coils of steel made before this mill was placed in operation could be handled by hand. But the development of this mill created a new condition inasmuch as the product in wide widths and long lengths must be handled in coils weighing up to $2^1/_2$ tons. The reeling device on the exit side of Nos. 5 and 6 cold mills, therefore, is of entirely new construction. After the strip sheet is entirely free of the mill and in coil form, a platform mounted on wheels and operating on a track moves beneath the coil and lifts it slightly, which causes the coiling drum to release its grip. The platform, still supporting the coil, returns to its starting position. The coil automatically is kicked off the platform and rolls on to the mill floor. (*Iron Trade Review*, vol. 80, nos. 20, 21, and 22, May 19, 26, and June 2, 1927, pp. 1271–1275, 1344–1346, and 1398–1400 and 1433; *The Iron Age*, vol. 119, no. 20, May 19, 1927, pp. 1435–1439)

LACLEDE STEEL CO., ALTON, ILL.

This mill was designed to produce hot-rolled strip up to 12 in. wide and from 0.035 to 0.375 in. thick. The strip is to be finished in flats or long coils, plain, pickled, and oiled and cold rolled.

The strip is rolled from billets in 30-ft. lengths. These are reheated in a continuous producer-gas-fired Morgan furnace from which they are pushed into a stand of vertical edging rolls and thence through a flying shear into the first pass of a four-stand 12-in. roughing train. The roughed-down section is conveyed through a 10-in. intermediate stand of rolls and then into a five-stand 10-in. finishing mill equipped with four-high rolls. In transit through the finishing stands the piece is given two edging passes and five flat passes. All stands of vertical edging rolls and five stands of four-high finishing rolls are direct motor driven, while the intermediate stand and the four roughing stands are rope

driven from the motor which drives the first stand of horizontal rolls in the finishing train.

The five finishing stands are equipped with four-high rolls, the working rolls being positioned between the top and bottom back-up rolls, the latter being mounted in roller bearings. An interesting feature of the motor control of the mill is the elaborate provision for keeping all control equipment housed so that dust will not affect it. The panels for the magnetic control for the hot-bed transfer crane and double motors are installed in the clean-air compartment of the fan house and in a separate brick building. A two-story brick building houses the air-filtering equipment. Air is drawn in through ducts in the roof and passed through four self-cleaning air filters of the traveling-cell type. On the ground floor is a blower with a capacity of 80,000 cu. ft. per min. This discharges clean air through a duct into the basement of the motor house which is kept under pressure of about 2 oz. From the basement the air passes through the foundations of the motor generators and mill generators to cool them and keep dust out of the windings. Air is discharged from the opposite end of the motor house through a series of louvers. (*Iron Trade Review*, vol. 80, no. 21, May 26, 1927, pp. 1329–1331; *The Iron Age*, vol. 119, no. 21, May 26, 1927, pp. 1525–1527)

Lukens Steel Co., Coatesville, Pa.

Reference is made to this installation because, while it does not roll sheets, it employs a four-high mill for rolling plate which is of interest to sheet rollers and to mechanical engineers, because the four-high mill is really the crux of the continuous sheet-rolling process. The mill is of the tandem type and consists of a two-high roughing stand followed by a four-high reversing stand. The working rolls are 23 in. in diameter and the back-up rolls 40 in. The back-up roll necks are equipped with roller bearings, in addition to which the finishing stand is equipped with a roll-changing rig which makes roll changing much easier and safer and reduces the time involved in changing. The screw-down is of the new differential type. An interesting feature of the installation is represented by a new shear. This is of a rotary type with two sets of cutting disks so that both edges of the plate may be cut at once. A distinctive feature of this sheet is that the bottom disk at each side is large and is so designed as to approximate or correspond to a flat block in an ordinary gage shear. A small top disk cuts against the large bottom disk. The result is that the sheared edges are flat and free from internal strains. (*Iron Trade Review*, vol. 80, no. 23, June 9, 1927, pp. 1475–1477)

Ashland Plant of the American Rolling Mill Co.

In the continuous sheet-rolling mill of the American Rolling Mill Co. at Ashland, Ky., a method of rolling is employed which is radically different from the accepted practice. It has been well known for a long time that in rolling, particularly hot rolling, the middle part of the roll is apt to get hotter than the ends, because the middle part does not lose heat quite as easily. If, therefore, a roll were made perfectly cylindrical when cold, it would be apt to belly out in the middle with the result that the piece rolled would become thinner in the middle and thicker at the edges. The ordinary way of counteracting this practice is to make the rolls slightly concave in the middle, so that when they expanded they would become cylindrical. Another method which has, however, nothing to do with the present discussion but which has been under development recently, is to turn the roll when it is hot instead of when it is cold, thus eliminating all guesswork.

In an investigation undertaken by the engineers of the American Rolling Mill Co., it was found at the outset that when a sheet passes between a pair of hot-mill rolls, the conditions are different from those which exist when the rolls are free of steel. A term "active pass," was invented, to describe the space between the rolls, while they are in engagement with the piece being rolled. Further tests have also indicated that rolls machined to true cylindrical form are not adapted to the rolling of wide sheets in thin gages.

Analysis of the Welsh system showed that the active passes were not always such that the rolls were truly cylindrical. In fact, it was demonstrated that the best controlled active passes were those in which the shape of the piece in the active pass was different from the shape of the piece before the pass. From this was developed a new method of continuous sheet rolling based on the principle of controlling various factors which enter into the formation of the active pass so that a piece is rolled with a slight convexity and each successive active pass reduces the convexity and makes the surface of the piece more parallel.

By properly controlling the prepared contour of the rolls, their spacing, and certain other factors, a way was found to roll a slight convexity into the piece and to reduce this convexity in each subsequent pass, thus forcing the piece to pass through the roll stand in a straight line as if in a closed pass.

In the Ashland plant the work starts with an ingot 19 by 39 in., weighing approximately 11,000 lb. This is broken down in the blooming mill to a slab 4 in. thick, 36 in. wide, and about 23 ft. long. The slab is cut into short lengths by a shear and rolled in a jobbing mill to a long thinner piece.

In this mill having seven two-high balanced stands, the 4-in. slab is reduced to a bar $^7/_{16}$ in. in thickness. From the bar mill the material is carried to the jobbing mill consisting of a train of four two-high balanced stands and three three-high stands, where the bar plates are reduced in thickness ranging from $^1/_4$ in. down to 16 gage with 13 gage about the average. Before the plates enter the continuous sheet mill they are subjected to certain processing which need not be described here. After passing through a continuous heat furnace 140 ft. in length, the plates go through five three-high stands. The sheets which have to be cold rolled undergo several further intermediary treatments before they pass to eight trains of rolls of from two to five stands each. In this case entirely different methods from those employed by the Columbia and Laclede steel companies are used. It is significant, however, that the plant has already shown itself to be capable of producing 1400 tons per day and an even greater capacity is in sight.

Rapid growth of the automobile industry created the problem of producing a quality sheet for automobile bodies which could be drawn into intricate shapes without damage to the surface. In the search for sheets with a more highly finished surface the fact was brought out that better surfaced rolls were essential. The turned roll was found to be too irregular and not sufficiently accurate, and the Armco practice is to grind all rolls.

Operation of the Ashland plant over a period of three years has brought to light a number of practical benefits. The saving of hand labor is obvious, since almost all of the processes performed by hand in the conventional type of sheet mill are executed here mechanically. The greatly increased production is found to lower substantially the cost of power per ton of sheets. Wastage is put at less than 15 per cent. On top of all this it is emphasized that the adoption of mechanical processing has not interfered with maintaining quality. Rather it is urged that the revolutionary development at Ashland is an answer to the challenge of sheet users for the manufacture in large quantities of sheets of the highest possible finish. Quality as well as quantity has been the demand, and the latter could not be marketed without the former, so the point is now made that quality is actually dependent upon tonnage in that uniformity of gage and surface call for continuity of operations.

The interesting feature of the Ashland plant is the use of three-high back-up rolls in the jobbing mill. In ordinary jobbing mills only two rolls are used to effect reduction. The principle of the four-high mill has been explained in the article on continuous sheet rolling in the May issue as due to the desire to employ small-diameter working rolls and yet provide for their sufficient mechanical strength. In the three-high Ashland plant only the bottom and middle rolls are working rolls, while the top roll is merely a back-up roll for the middle roll. The top and bottom rolls are 30 in. in diameter and the middle roll 14 in. in diameter. Only the bottom rolls are driven by power, the back-up roll being moved solely by friction with the middle roll, which, in turn, is driven by friction with the bottom roll. While it is not explained why a large bottom roll instead of the arrangement in four-high mills is used, the idea is apparently to use the small middle roll as a "bite," and in this way combine most of the advantages of the four-high mill with the lower cost and simplified curve of this type of a three-high mill.

When rolling hot metal of comparatively small thickness the rate of cooling is rapid. Therefore the speed of the rolls is increased in the successive stands so that less heat is lost by radiation for a given reduction than if the steel were rolled at a lower speed. Moreover, rolling the steel in one direction increases its length in that direction so that the rate of travel of the reduced piece is higher than the piece entering the roll.

The bottom rolls of this three-high group are coupled with a secondary drive and a single reduction-gear set to an 1800-hp. motor, its speed being varied by a Sherbius regulating set which operates from 240 to 360 r.p.m. By this arrangement the rolls in No. 5 can be operated from 43.2 to 64.6 r.p.m. which is equal to a delivery speed of 340 to 507 ft. per min.; those in No. 6 stand from 51 to 66.5 r.p.m., or from 400 to 600 ft. per min.; and those in No. 7 stand from 57 to 85 r.p.m. or from 444 to 666 ft. per min. The screw-down levers on all of the jobbing mills are operated from a runway which is elevated between each pair of housings and which connects with all stands.

The bar-mill layout has the rolls arranged in tandem, the slab emerging from one set of rolls before it is engaged by another.

In tandem mills difficulty frequently is encountered in obtaining

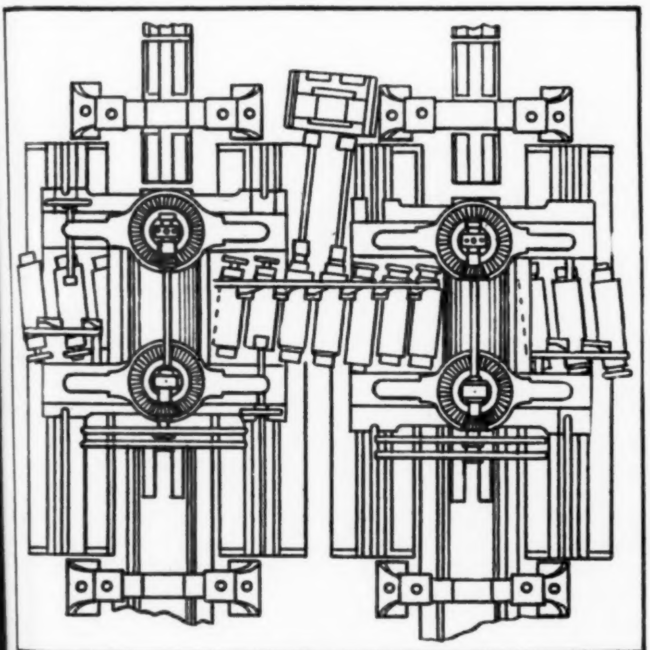


Fig. 1 Plan View of the Skew-Type Feed Table Installed Between Horizontal Stands Nos. 1 and 2, 3 and 4, and 5 and 6 of the Bar Plate Mill, Ashland Plant of the American Rolling Mill Co.

an accurate placing of the piece with regard to the numerous stands of rolls because the rolling action, due to the improper fit of the rolls to the piece, is not always perfect. Feed tables equipped with side guides usually are employed to enforce a given path to the material in transit between stands but the force imparted to the piece by the driven rollers frequently is not sufficient to force it to pass between two guides where any jamming occurs. Moreover, the piece has a tendency to curl at the ends due to the roller action and this curled portion often will force its way down between the rolls in the feed table.

This, however, is avoided in the set-up between the horizontal stands of the bar plate mill by using a table in which the rollers are arranged askew to the desired line of feed, and in which the stands of rolls are offset slightly so as to be out of true center line with each other. The side guide structure, in this case, acts to enforce a straight-line movement to the piece and the skewed rollers to keep the piece up against the side guides. The purpose of staggering the roll stands is to permit the piece to become aligned with the guides, thus avoiding the chance of jamming between stands.

The tendency of the skewed rollers is to force the piece to travel in a direction at right angles to the faces of the rolls. This tendency is opposed by the side guides with the result that the piece takes a straight-line contact along the edge of the right guide only. As the piece enters the No. 2 stand it is centered between and when it emerges the rollers force it against the left side guide. The guide pieces or flights, which lie between each roll of the skew table, are designed to present slanting surfaces at points where the pieces in transit would tend to jam, thus preventing the piece buckling between the rolls of the feed table. (*Iron Trade Review*, vol. 80, nos. 24, 25, and 26, June 16, 23, and 30, pp. 1532–1535, 1594–1596, and 1656–1659; *The Iron Age*, vol. 119, no. 24, June 16, pp. 1731–1737 and 1792)

Short Abstracts of the Month

ELECTRICAL ENGINEERING

Miguet Electrode and Miguet Furnace

A novel feature of this furnace lies in the fact that an enormous current as high as 240,000 amperes single-phase is carried through a single electrode. This is done by leading the current to a single

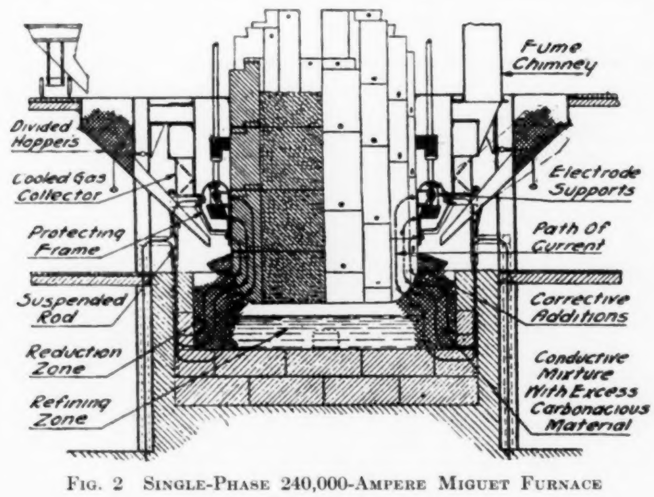


Fig. 2 Single-Phase 240,000-Ampere Miguet Furnace

electrode through a number of separate circuits symmetrically arranged around the furnace (Fig. 2).

The high current capacity requires a large cross-section of the electrode and sectional construction of the latter has been selected. The electrode is built by piecing together prebaked carbon segments assembled by dove-tailing the ends and by bolts in the horizontal axis. To add and assemble the new electrode segments, a platform has been provided directly above the furnace. The feeding of the latter is done mechanically through divided hoppers which can be operated separately or simultaneously. A circular reduction zone is one of the peculiarities of this furnace. The reaction or reduction takes place only along the edge. No current or arc passes from the bottom of the electrode to the bath below, as the bottom of the electrode is maintained about 8 in. above the bath. A high efficiency is claimed for the Miguet furnaces. A 5000-kw. unit in operation in France during 1926 gave an average production of one metric ton of calcium carbide for 3100 kw-hr., which is less than for three-phase furnaces. (Marcel Arrouet. Paper before The American Electrochemical Society, Philadelphia, April, 1927, abstracted through *The Metal Industry* (London), vol. 30, no. 20, May 20, 1927, p. 509, 1 fig., *d*)

FUELS AND FIRING

Hydrogenation of Coal

Data and research now being conducted by V. G. Skinner and J. Ivan Graham of Birmingham University for the British Colliery Owners' Research Association. Coals of various kinds have been treated with hydrogen under a pressure in the neighborhood of 120 atmos. and at a temperature of about 430 deg. cent. (806 deg. fahr.). The results indicated that brown coal (German) and lignite

(Devonshire) did not give an appreciably greater tar-oil yield than the bituminous coals previously tested, although the characteristics of the oil produced were somewhat different. One of the coals included in the program was cannel coal which is noted for its high oil yield when carbonized at a comparatively low temperature.

There are two main types of cannels, the boghead coal and the hard black material frequently found in bituminous coal seams. The carbonaceous materials in the two are quite different as the original article states, and the results obtained by hydrogenation were likewise very different. (*Fuel in Science and Practice*, vol. 6, no. 2, abstracted through *The Colliery Guardian*, vol. 133, no. 3466, June 3, 1927, pp. 1292–1293, *e*)

INTERNAL-COMBUSTION ENGINEERING

Acro Oil Engine

The Acro engine was developed with the idea of producing a high-speed unit. Fig. 3 shows the special design of piston at top dead center in the cylinder of an engine of the ordinary four-stroke type. In this position the clearance volume consists of the four parts: *a*, the compression space in the piston; *c*, the compression space between the top of the piston and the cylinder head (the volume of this space naturally changes as the piston

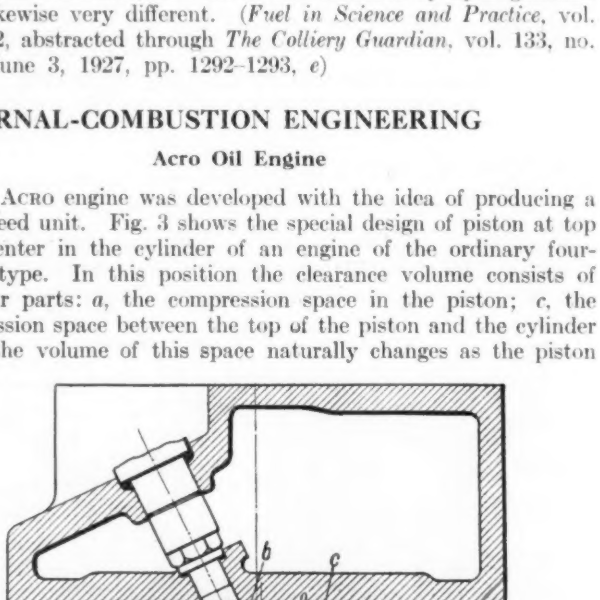


Fig. 3 Combustion Chamber of Acro Oil Engine

moves down the stroke); *b*, a Venturi or funnel-shaped passage connecting *a* and *c*, of which *d* is the orifice or neck. The fuel is injected into the space *b*. The engine tested was a single-cylinder engine of 125-mm. bore and 180-mm. stroke (4.92 and 7.08 in.), with a connecting-rod-to-crank ratio of 3.8 and with a normal speed of 800 r.p.m. These dimensions have a swept volume of 2209 cu. cm. (134.8 cu. in.). The total clearance volume was 140 cu. cm. (8.5 cu. in.), divided as follows: *a*, 98 cu. cm. (5.9 cu. in.); *b*, 10 cu. cm. (0.6 cu. in.); *c*, 32 cu. cm. (1.95 cu. in.), or 70, 7, and 23 per cent of the clearance volume, respectively. The cross-section of *d* was 1.17 sq. cm. (0.17 sq. in.).

The engine was an ordinary high-speed "airless" injection engine, which was only altered as far as the cylinder head and the piston were concerned. The fuel was injected in the ordinary way directly into the Venturi-shaped space *b*, the fuel valve closing at about 15 deg. after top dead center.

In order to avoid any confusion between this engine and existing engines in which the combustion spaces are divided into two parts, giving an "ante-combustion chamber," the author quoted Professor Nagel's statement that "the distinguishing feature of such engines is a definite throttling action in the passage connecting the 'ante-combustion chamber' and the main combustion chamber, the passage being so proportioned that, upon the burning in the former of a portion of the charge, the consequent rise of pressure forces the remainder of the charge at high velocity through the restricting passage."

Professor Stribeck carried out two series of tests; the first upon the differences in pressure between the parts *a* and *c* of the compression volume during the compression period. The second series of tests gave a comprehensive indication of the temperature changes taking place during combustion and expansion at the points marked 10 to 70 in Fig. 3, these numbers giving the distances in millimeters from the under side of the cylinder head to the respective points. In considering these points it was borne in mind that during the power stroke combustion would cause a rise of temperature while expansion would cause a drop, and that the highest temperatures would be reached where the mixtures of fuel and air were in the correct proportions. From diagrams in the original article it would appear that only at points 0, 10, 20, and 30 did the temperature reach a high level and then only while these points were in the Venturi-shaped space *b* of the piston. It is safe to conclude that combustion takes place almost entirely within *b* and that the mixtures of fuel and air are constantly favorable during the combustion period.

The tests are said to show the difference between this engine and those of the ante-combustion chamber type. Tests made to investigate the effect of speed are especially interesting. The results show that the hot zone extends about 30 mm. into the cylinder after 8 mm. of piston travel, and that the maximum temperature reached does not differ much for 400 and 800 r.p.m., but at 600 r.p.m. is higher. The figures are:

Speed, r.p.m.	400	400	600	800
Mean indicated pressure, lb. per sq. in.	47	68	82	77
Highest temperature at 8 mm. piston travel, deg. cent.	1350	1300	1650	1370

The ratios of the times necessary for the same piston travel are as 4 : 3 : 2. Thus the flame develops twice as fast at 800 r.p.m. and more than $1^1/_2$ times as fast at 600 r.p.m. as at 400 r.p.m. Whether the speed of combustion is proportional to the speed of revolution, as it appears to be, i.e., whether at speeds so different as 400 and 800 r.p.m., the same amount of fuel is burned in the same crank angle, is still open. This question is well worthy of investigation, since, if this is the case, this type of engine could develop much higher speeds. The author found nothing to indicate the contrary. The test engine ran at speeds from 200 to 800 r.p.m. smoothly, and with a clear exhaust from no load to full load. On the assumption that the combustion rate is proportional to speed of revolution, the maximum possible load with clear exhaust should be practically the same at all speeds. The tests showed the following results:

Speed, r.p.m.	200	400	600	800
Mean indicated pressure, lb. per sq. in.	97	101	93	91

These differences are really small, and the efficiency of combustion, as shown by the fuel consumptions at all loads over this range of speed, is also remarkably consistent.

For the combustion to be more rapid, it is necessary for the velocity of the air from *a* to *c* to be higher. That this is so is shown by the pressure tests. These are, however, limited to the compression stroke, since the vibrations of the testing diaphragm near top dead center made later readings unreliable. At 20 deg. before top dead center the following excess pressures in *a* over those in *c* were found at different speeds:

Speed, r.p.m.	200	300	540	800
Excess of pressure in *a* over *c*, lb. per sq. in.	3	4	11	25

Assuming that the velocity of flow is proportional to the square root of the pressure difference, the following results are obtained:

Ratio of speeds of revolution	0.25	0.38	0.68	1.0
Ratio of velocities	0.34	0.4	0.68	1.0

The automatic adjustment of the rate of combustion to the speed of the engine is thus explained by the fact that the rate of flow of the air is almost directly proportional to the revolutions per minute of the engine. The engine thus gives that flexibility essential for use in an automobile.

To obtain a value for the velocity of flow, it may be assumed that at 800 r.p.m. and at 20 deg. after top dead center the excess pressure is 17 lb. per sq. in., a probable value. At a gas temperature of 700 deg. cent. (1292 deg. fahr.) and under stable conditions, the velocity would be 500 ft. per sec.; the corresponding velocity at 300 r.p.m. would be 0.4 × 500 = 200 ft. per sec.

The investigation shows that the Venturi-shaped portion is of great importance, as ignition and the greater part of the combustion take place in it. The restriction of the combustion to a small part of the compression space results in a clear separation during the process between the new air and the exhaust gases and thus a high temperature of combustion may be reached. This restriction of the combustion and the adjustment of the air flow to the engine speed are the essential characteristics of this type of engine. (Paper by Dr. of Engrg., R. Stribeck of Stuttgart, before the summer meeting of the Verein deutscher Ingenieure, May, 1927. Abstracted through *The Engineer*, vol. 143, no. 3726, June 10, 1927, pp. 632–633, *de*. Complete paper in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 71, no. 22, May 28, 1927, pp. 765–774, 30 figs.)

Valve Gear for Four Valves per Cylinder

Description of a design recently patented by A. H. Wilde, chief engineer of the Hotchkiss Automobile Co., of Paris, which combines the advantages of reduced overall height with availability of space necessary for mounting the intake and exhaust manifolds. In this design two camshafts are used for each line of cylinders. Each tappet and its camshaft lie in a plane parallel to that containing one pair of valves. A common tappet imparts the movement to two inlet or exhaust valves by means of two rockers having their axes at right angles to the plane of the tappet, the rockers being held in bearings in the camshaft casing by a split cap. The tappets are guided in a bushed hole in the upper part of the cam casing forming the cap, and there is but one tappet for each pair of valves. The two rocker ends moved by the common tappet are slightly off-set and inserted through a slot in the tappet itself, motion being imparted through a hardened washer let into the inside of the tappet. (*The Automobile Engineer*, vol. 17, no. 229, June, 1927, p. 226, 2 figs., *d*)

The "Watch Tower" Model Oil Power Plant

The equipment recently installed by the Watch Tower Bible and Tract Society of Brooklyn is considered as an example of oil-engine equipment operating under virtually ideal conditions. One of the most interesting features is the cooling system.

For cooling-water circulation a Davidson centrifugal pump, driven by a Star motor, is installed. The pump is designed for a hundred-foot head and at this head has a capacity of 70 gal. per min. at 1850 r.p.m. The cooling-water system is arranged so that city water can flow through the cooling jackets to waste, or can be recirculated through a cooling tower on the roof, using city water for the make-up supply. A roof tank is cut into this recirculating system and is arranged so that it can be drained in cold weather to prevent any possibility of ice formation. All of the valves controlling the water circulation are located in the engine room, centralizing this control in a position adjacent to the water pumps which are mounted on a concrete ledge at one side of the engine room.

An additional factor of safety is achieved in this system by the provision of a Brown recording instrument which indicates the level of water in the roof tank on a chart in the engine room. A change of one foot in the water level of the 1500-gal. roof tank will cause an alarm bell to ring, warning the operator of an impending shortage in his water supply. Richardson-Phoenix sight-flow indicators are fitted to the cooling-water outlet of each engine and these have a Bowser electric connection arranged to cause an alarm bell to ring if the water supply fails. Motoco dial thermometers reading up to 212 deg. fahr. are located in the water inlet and outlet connections of each engine.

An all-steel cooling tower is now under construction and will be installed on the roof to handle the recirculated jacket water. The hot water coming from the engines is also passed through the hot-water system of the building and is used for showers, washing, etc.

It will thus be seen that unusual precautions have been taken to insure constant and accurate supervision of the cooling-water supply, but the resulting ease of control makes for such reliability and simplicity of operation that these refinements may be accepted as well-established installation practice. (*Oil Engine Power*, vol. 5, no. 6, June, 1927, pp. 381–385, illustr., *d*)

MACHINE PARTS

Component Crankshaft

Description of a built-up crankshaft used in the new 1.5 litre six-cylinder engine which the Acédès Company built for racing purposes. The shaft as shown in Fig. 4 is so designed that each web is a disk with the journal or pin forged integral with it. There are twelve such disks, the one at the forward end carrying the spigot for the supercharger drive, while the rear one carries the taper with attachment to the flywheel.

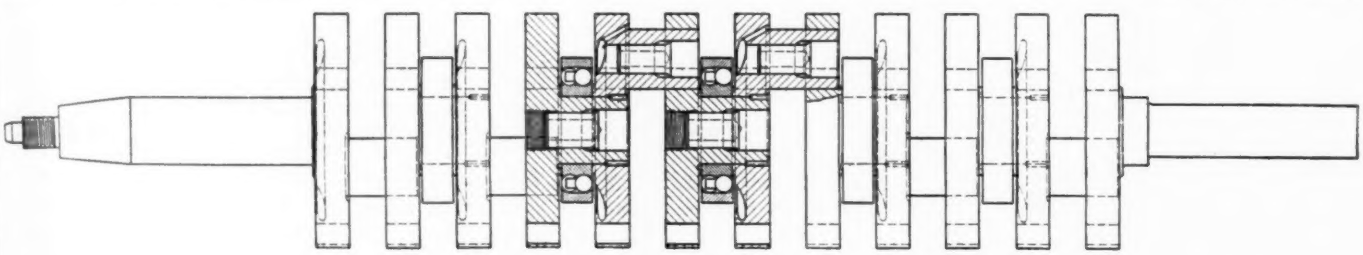


Fig. 4 Built-up Crankshaft of the Acédès Racing Car

The following arrangement has been provided for attaching the pins and journals to the webs. Each pin is hollow with two internal diameters, the larger being tapered to the extent of 0.005 in. and accurately ground to receive tapered expanders which are forced into position under a press. The proper angle and length of taper are very important. In addition to the tightness obtained by means of the expander small holes are drilled half in the web and half in the pin into which silver-steel driving pins are inserted before the expander is forced home. These driving pins are used only on the main bearings. The connecting-rod bearings are of the uncaged roller type, the big ends being split for assembly purposes, and the rollers running direct on the pins. The connecting rod is of nickel-chrome case-hardened steel and the rollers of silver steel. This design has permitted the construction of a very short shaft. The bore of the six-cylinder engine is 60 mm. (2.36 in.) and there are seven bearings, yet between the end bearings the length is only 19¼ in. The strength of webs is well above the average, the disk being $^{13}/_{16}$ in. thick, which is equal to the gap between them. One of the advantages of this form of construction is that the shaft can be dismantled in the event of a broken ball and re-assembled without any special tools, except the locating rods or the guide tube. (*The Automobile Engineer*, vol. 17, no. 229, June, 1927, pp. 225–226, 2 figs., *d*)

Trogon-Montalembert Speed Changer

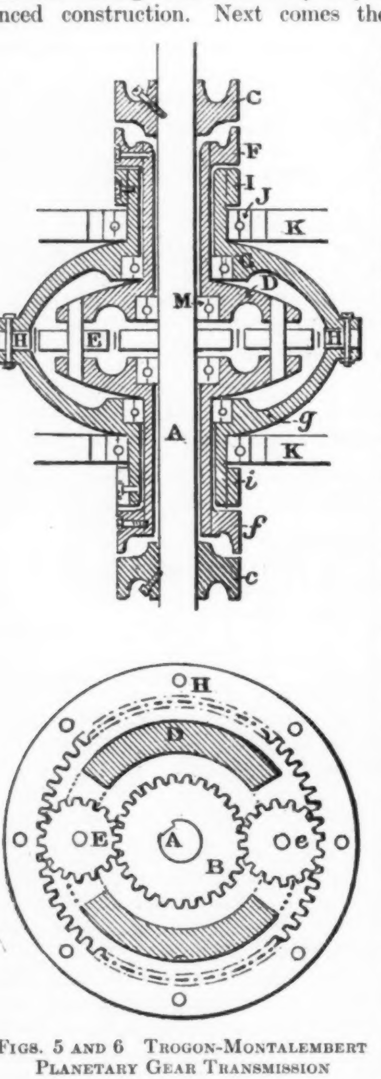
In this device five forward speeds and two reverse can be obtained with only one main gear and two pinions. It is of the planetary type as shown from Figs. 5 and 6, but differs from other similar devices, such as the Ford, by its ability to give more speeds. The device consists of three main concentric portions: first, shaft *A* which carries a toothed gear *B* and two pulleys *C* and *c*, the gear being keyed to the shaft. Next is a tube structure *D* carry-

ing two pinions E and e freely rotating on their shafts and two similar pulleys F and f attached to their ends. As a matter of fact, however, only one of these pinions is needed to do the work, the other being used extensively to provide a symmetrical and balanced construction. Next comes the tubular piece consisting of two shells G and g carrying, riveted between them, the large internal gear-wheel H and two similar pulleys I and i at its extremities.

This last piece forming the casing is supported by two ball bearings which in themselves are carried by the chassis K; the ball bearings L and M (L is not shown in Fig. 5, however) lie between the concentric parts of the device.

The characteristic feature of this arrangement consists in the application of the driving force alternately between the three concentric pieces and this is what makes it possible to obtain seven speeds, one of them being the direct drive.

The motor power is applied to one of the pulleys C, F, or I and the same force is taken up by the opposite part of the same character c, f, or i, through the means indicated above, transmitting it, however, at different ratios. It must be borne in mind, however, if the force is applied at C, and, let us say, taken up through i (this being the first speed) the pulleys F and f must be held stationary and the same applies to all the other combinations. When the speed is transmitted from one to the other of such devices, the third concentric piece or the pulleys acting on it must be automatically held stationary. (*La Pratique des Industries Mécaniques*, vol. 10, no. 3, June, 1927, p. 106, *d*)



Figs. 5 and 6 Trogon-Montalembert Planetary Gear Transmission

Bearings for Use in Rolling Mills

The use of roller bearings in rolling mills has been steadily increasing until at the present time about 60 per cent of the bearings in rolling-mill auxiliary equipment are of the roller type. The outstanding feature of roller bearings is the large saving of power. In addition, and because of quantity production of roller bearings up to about 7 in. diameter, the cost has been reduced to a point that the total installation cost of a roller bearing is practically the same as a bronze or babbitt bearing. On the other hand, the design of mill-roll bearings used for blooming, plate, universal, billet, bar, and merchant mills has undergone very little change up to the present time and grease is invariably used for the lubricant. Bronze-bushed bearings have been recently designed for continuous lubrication but no data on their operation are available. Mill pinion bearings have undergone considerably more changes in the way of improvement than the bearings of the rolls which they drive. The design of this type of bearing is limited by the fact that the distance between the bearings is very small compared to the size. The introduction of cut-tooth pinions made necessary more accurate mounting and more efficient means of lubrication. At first an effort was made to use a lighter oil for the pinion bearings and a heavy oil or grease for the pinion-tooth lubrication. Now, however, oils are available which can be used for the lubrication of pinion teeth as well as the journals which carry the pinions. This simplified the design of the bearings, saved about 10 to 12 in. of the length of the pinions, and eliminated many complications.

There has been a material improvement in drive and flywheel unit bearings. Elaborate designs have been worked out where extremely high spots and loads are encountered, such as on overhung flywheel pinion shafts.

Ball and socket, ring, or force-feed oil lubricated, water-cooled bearings have proved to be the most effective. Roller bearings for drives of this character have become standard only quite recently. Illustrations in the original article show some of the typical bearing arrangements as used on mill roll necks. There is quite a variety of mountings for doing practically the same kind of work and this is said to be due partly to the desire on the part of some who have become familiar with a certain type to have it duplicated. A discussion of the overhung flywheel and its use is given in the original article. (C. J. Klein, Engrg. Dept., United Engineering and Foundry Co., Pittsburgh, Pa., in *Iron and Steel Engineer*, vol. 4, no. 6, June, 1927, pp. 271–274, 5 figs., *d*)

MARINE ENGINEERING

Re-engined Liner

A piece of work which is interesting, not only for the results which have been obtained but also for the conditions under which it was carried out, has just been completed on the Clyde by the Fairfield Shipbuilding and Engineering Company in the shape of the re-engining of the Canadian Pacific liner *Empress of Australia*.

Built in Germany before the war and intended for the South American service but never put into commission, this vessel, originally named *Tirpitz*, passed into the hands of the British government as reparations tonnage and was eventually purchased by the Canadian Pacific, who put her on their Vancouver-China service. Her machinery then consisted of two sets of high-speed impulse-reaction turbines, driving twin-screw propellers through Föttinger hydraulic transformers. Great things were expected of this system by its sponsors when it was introduced, but on the Pacific it did not prove satisfactory, as the anticipated speed could not be obtained with the ship and the fuel consumption was very high. As she was practically a new vessel with very fine passenger accommodation, it was decided to re-engine her, and after the claims of the direct Diesel, the Diesel-electric, the Diesel-hydraulic, and the turbo-electric drives had been considered, it was decided to fit a single-reduction geared turbine installation.

Each of the two independent sets of engines comprised in the new machinery consists of a high-pressure, an intermediate-pressure, and a low-pressure Parsons' type turbine, and the combined installation is designed to develop 20,000 s.hp. on service with a propeller speed of 125 r.p.m. In the intermediate and low-pressure casings are incorporated high-pressure and low-pressure turbines, giving a total astern power of 14,000 s.hp. and provision is made to supply steam direct to any of the turbines in case of necessity. The main condensers are of the Weir regenerative type designed for very high vacuum and having cupro-nickel tubes. Instead of the 14 water-tube boilers formerly employed there are now six main double-ended Scotch boilers working at a pressure of 220 lb. per sq. in. and fitted with North-Eastern Marine superheaters, giving a superheat of 240 deg. fahr. In addition there is one single-ended boiler intended to supply the auxiliary machinery and also connected to the main steam range. The double-ended boilers work under the Howden forced-draft air system, the air being supplied by four electrically driven fans, and they are fitted with large air heaters of the Howden tubular type. The oil-fuel burning installation is on the Todd system. Electric current for the general service of the ship and for driving some of the auxiliaries is supplied by two Diesel-engine generators, each of 165 kw. These are balanced on the Lanchester system in order to avoid the vibration to which the Diesel generators give rise in some motorships. The four steam turbo-generators originally fitted have been retained as stand-bys.

A radical departure from standard practice has been adopted in connection with the seating for the turbines and gearing. Instead of building plate and angle-bar stools as usual for machinery of this type, the gear case has been extended downward and constructed with a flat base, so that there is a well-distributed foundation for attachment to a comparatively shallow box seat built on the tank top. The turbines, as usual in geared installations, are situated at a considerable height above the tank top, necessitating high erections for their support. A massive cast-iron stool is fitted at the forward end to embrace the feet of each set of turbines, and this stool, seated directly on the tank top, dispenses entirely with the usual plate and angle-iron structure. This method of constructing the seating has been adopted with the object of reducing the transmission of vibration and eliminating as far as possible racking strains on the ship work.

To suit the new machinery the line of shafting has been entirely altered, the vertical rake being increased 2 ft. 3 in. at the forward end of a length of about 150 ft. This change entailed re-boring the stern and fitting new stern tubes. The propellers now turn inward, instead of outward as they did originally. This alteration was made because experiments in the William Froude tank at Teddington indicated that, in this ship, it would result in an appreciable gain of propulsive efficiency. The new propellers are of the solid four-bladed type.

The combined result of all the efforts made to secure efficiency and economy in boilers, turbines, auxiliaries, and screws, while rendering the ship suitable to meet the requirements of her new service, was revealed by the sea trials. On the measured mile a mean speed of 20.345 knots was recorded, and during the extended trial at 20.440 s.hp. the consumption of oil fuel was 0.69 lb. per s.hp-hr. for the main and auxiliary machinery, including steering gear but excluding deck services. This performance corresponds to an aggregate consumption of 150 tons of fuel oil per day for all purposes at a speed of 19 knots in good weather. With the original machinery the maximum speed obtained on a full-power trial was 17.2 knots, and the best sea speed on a number of voyages was $16^1/_2$ knots on a gross consumption of 205 tons of oil a day. What this means in the way of economy may be illustrated by the statement that if the ship were to be run at her previous service speed of $16^1/_2$ knots she would consume 100 tons a day, or less than half the amount required with her old machinery. It may be mentioned that special precautions were taken to ensure accuracy in the records of fuel and water consumption and other figures obtained in the trials. (*The Times Trade and Engineering Supplement*, vol. 20, no. 467, June 18, 1927, p. 326, *d*)

Self-Unloading Steamer *Valley Camp*

The various unloading apparatus seen along the wharves suffer from one cardinal defect. The cargo to be discharged by their means can only be removed from the ship at a particular point of the port concerned. There are many places, particularly in partly developed countries, where, because of absence of such apparatus, crude manual methods have to be adopted. It is because of this that self-unloading apparatus for vessels have been introduced. A self-unloading gear may consist of a conveyor boom on the deck which can be swung outboard on either beam and on to which the cargo is delivered by scrapers moving in tunnels in the bottoms of the holds. This system is quite popular on the Great Lakes and the St. Lawrence. The first vessel of the kind was built in England by the Neptune Works of Swan, Hunter and Wigham Richardson, Ltd., Newcastle-on-Tyne. This vessel is the *Valley Camp*.

The self-unloading gear was designed by L. G. Smith of Sturgeon Bay, Wis., but cannot be described here because of lack of space. (*Engineering*, vol. 123, no. 3204, June 10, 1927, pp. 695–698, illustr., *d*)

MECHANICS

The Meaning of Centrifugal Force

The author claims that the meaning of centrifugal force is often misunderstood and attempts to present a satisfactory explanation thereof. It is a misconception to think that centrifugal force is an external force acting on all bodies having rotary motion and that it contributes to this motion in the same manner as does the force of gravity or a force due to a pull or a push. Centrifugal force cannot form a part of the system of external forces on the rotating body because there is no agent available to impress that force upon the body. To show this he offers a proposition which makes it possible to determine whether a force is or is not acting upon a body at any point.

This proposition is expressed as follows: "There are two ways only in which a force can be brought to act upon a body: one way is by means of physical contact of another body with it, the other way is by means of a field of force, such as a gravitational field or a magnetic field."

He next establishes the truth of D'Alembert's principle (impressed forces on a body are in equilibrium with the reversed effective forces). Considered from the point of view of D'Alembert's principle, centrifugal force is merely one of a set of forces which have to be added in the case of pure rotation or plane motion in order to restore the body to equilibrium. It has no greater claim to reality than the remaining force in this method. (M. M. Frocht, Asst. Prof. of Mechanics, Carnegie Inst. of Technology, in *The Journal of Engineering Education*, New Series, vol. 17, no. 10, June, 1927, pp. 907–918, 7 figs., *t*)

METALLURGY

Low-Temperature Reduction of Iron Ore

By low-temperature reduction of iron ore is meant a process in which reduction occurs at temperatures much lower than used in blast furnaces. Such processes employ carbon as the main reducing agent although hydrogen has also been tried. The carbon may be added as free carbon, carbon monoxide, carbon dioxide, or gases containing carbon or hydrocarbons. There are a number of such processes, such as the Greaves-Etchell's, Carsil (Mechanical Engineering, vol. 49, no. 6, June, 1927, p. 686), Hornsey (Mechanical Engineering, vol. 46, no. 8, Aug., 1924, p. 491, and vol. 49, no. 1, Jan., 1927, p. 54), Croese, Edwin, etc. Some of these processes, such as those of Flodin and Gronwall, use electricity.

One of the most interesting is that developed by the Norwegian metallurgist, E. Edwin, in coöperation with several German concerns. The process is of a gaseous reduction type and the chief novelty lies in the effective regeneration of the carbon dioxide produced into the carbon monoxide.

Two processes for low-temperature reduction have been tried out in California. The Triumph Steel Co. has been carrying on experimental work for some years on the black magnetite sands of Santa Cruz County. Pure magnetite or a mixture of magnetite with ilmenite or chromite is fed into a rotating electrically heated tube or kiln 3 ft. in diameter and 35 ft. long. The lining of the tube has nichrome heating elements embedded in it. Crude oil is sprayed into the feed end of the furnace as the magnetite passes through it. This oil is gasified and serves to reduce the iron oxides. Sponge iron is produced at the lower end of the tube and is briquetted into the form of billets. The exhaust furnace gases are treated for by-products and then used under boilers or driers.

The other development is operated by the Wakama Iron & Steel Co. and utilizes a process designed by H. B. Bardue of San Francisco. This process consists of taking pulverized iron ore and thoroughly mixing it with carbonaceous fuel, either liquid or solid. The mixture of ore and carbon is placed in cylindrical or spherical metal retorts. These retorts are then rolled into the cooler end of a long, sloping-hearth reverberatory furnace similar to the furnaces used for a rolling mill. This furnace is partially heated at the discharge end, but mainly kept hot by the combustion of carbon monoxide and gases produced in the retorts or shells. The discharge end of the furnace is kept at a bright red heat and the oxide in the ore is reduced, leaving a semi-metallic sponge sintered into the porous mass about as coherent as a half-burnt brick. (Frank Hudson and Oliver Smalley. Paper presented before the American Chemical Society, Philadelphia, April, 1927. Abstracted through *Iron and Steel of Canada*, vol. 10, no. 5, May, 1927, pp. 146–151 and 158, 5 figs., *d*)

POWER-PLANT ENGINEERING

Heat, Light, and Power in the Pulp and Paper Industry

At the general meeting of the twelfth annual convention of the Technical Association of the Pulp and Paper Industry, New York, Feb. 22 and following, 1927, a session was held on heat, light, and power, at which a paper by S. A. Staege and C. U. Smith was presented on the Power Requirements of Paper-Mill Machinery.

The authors pointed out that the paper machine is an outstanding example of marked economies in power consumption that have been effected in the past few years, though much remains to be done. Improved bearings for table and felt rolls have come into general use. Calender bearings have been so improved in design and construction that in best modern practice today a calender stack requires no more than half or one-third of the power necessary for a stack of similar size and speed only a few years ago, and in the best present-day practice the paper-machine driers take no more than one-third of the power necessary only four or five years ago. The elimination of the old style driers frequently effects a saving in power of from 25 to 50 per cent.

The original article contains a table showing some of the low-power machines in the industry today. The power requirements of beaters are discussed to some extent. A chart is presented showing the horsepower requirements for various conditions. Another table shows some typical cases of jordan drives.

This paper called forth considerable discussion. In answering it the authors stated, among other things, that although the running load on the driers was exceedingly low, the starting torque was almost as high as in the case of driers which take a very much higher running load.

Their analysis of the situation was as follows: "That with anything like reasonable bearing design there is practically a metal-to-metal coefficient of friction on starting up, due to the fact that the temperature is so high and the weight on the journal so great that the oil film in the journal bearing is broken down and, therefore, it takes pretty nearly the same amount of torque to start the driers regardless of the design, but after you once get them rolling and a film of oil forms under the journal, then in the good bearing, which has an ample surface of uniform character so that a good oil film can be maintained throughout the surface of the journal, you get a low power consumption."

They thought the next step that should be undertaken by machine builders was to produce a design where the starting torque would not be so high. Even though a drier might not take more than 10 or 15 hp. to drive it, one might have to have 150 hp. torque or more to start it, which means one has to have bigger driving equipment and heavier stresses on drier gears and all of the equipment just to start the section. They believed that it could be done. It was a subject on which they would like to hear from the machine builders as to what they thought about the situation.

Years ago, when driers took about 0.0018 kw. per in. width per 100 ft. speed per drier roll, it took only about five times as much torque to start the drier as it did to keep it running. Now when the power was down to less than one-quarter of that, it took from 20 to 25 times as much running torque in some cases to start the driers as it did to keep them running. That sounded like a ridiculous situation under which to operate. (S. A. Staege (Mem. A.S.M.E.) and C. U. Smith in *Technical Association Papers*, Technical Association of the Pulp and Paper Industry, vol. 10, no. 1, June, 1927, original paper pp. 48–50, 1 fig., and discussion pp. 212–218, 3 figs., *g*)

RESEARCH

Research in a Textile Establishment

The present article is based on the practice of the Pacific Mills. According to the author, in his organization, at least, a much more receptive attitude toward new developments prevails. Some years ago his company started a research laboratory with a complete experimental mill said to be the only one of its kind in existence. Money was spent for three years before results showed and then one improvement paid for the entire previous expense, while other improvements began to come along to it.

Research in the Pacific Mills organization is not restricted to chemical tests and one of the most useful opportunities for research is seen in the development of more intelligent use of man power.

Modern operatives are machine tenders. The machine does the work so long as it is supplied with material and nothing goes wrong. The man has to step in in this latter case. Cotton-mill operatives are not doing their most productive work when threads break. The thread breaks when the exception occurs in the material. Therefore the problem of research is to make the material more uniform. The campaign for greater uniformity started with raw materials. The mills made their own survey of the cotton region, studied the kind of cotton grown in each section and even the uniformity of the local type. They measured the fiber lengths and charted the measurements to show not only the average length of the fibers in a lot but the maximum and minimum variations and what proportion of the entire lot clustered close to the average. While making a survey of cotton sources the mills established direct permanent contacts. As a result they can buy more intelligently and do not have to depend entirely upon intermediary parties in the cotton brokerage market.

Uniformity of raw material enables better adjustment of all machines as far up as weaving. For instance, the fiber length of raw cotton determines adjustment of rolls. Take the machine which straightens cotton fibers and assemblés them into a continuous sliver. A set of corrugated rolls feeds the fiber forward to be caught by a near-by set of parallel rolls running faster, which pulls the fibers forward before the first rolls have quite released them, thus straightening each fiber. Obviously the distance apart of the two sets of rolls is determined by the length of the fiber. Rolls can be adjusted for different large lots, but cannot be re-adjusted instantly for the varying fibers within a lot. On a given lot, the rolls are set for the average length on that lot.

The occasional fibers so excessively short as not to reach across gap between the rolls receive little or no pull and are not straightened into place. Excessively long fibers may be stretched too much and broken, weakening the subsequent yarn. Regardless of the variety between different lots, it is important to reduce the variety within any one lot, so it is worth while to be able to get lots uniform within themselves, even if this means going all the way back to the cotton fields. This requires knowledge of the facts; not the traditional facts, but the facts from decade to decade, year to year, and season to season, as conditions change without anyone's volition or control.

For quick routine measurement of fiber lengths and variations the research laboratory developed a machine which is supplied to each of their plants for examining samples of their daily shipments of cotton as received. Samples of cotton about to go into process became a guide to the adjustment of machines. It is merely an organized mechanism for quick fact-finding and for translating the facts into savings.

The work of the laboratory did not stop at the sliver. The uniformity of yarn made from these slivers was studied next and from this the laboratory naturally passed to the character of the cloth made from the yarn. Some of the methods for securing the men for the laboratories are described. (E. F. Greene, Treasurer, Pacific Mills, in *Factory*, vol. 38, no. 6, June, 1927, pp. 1076–1078 and 1202–1208, illustrated, *dp*)

SAFETY

Wire-Drawing Blocks

The Bethlehem Steel Co. has recently completed and put into operation at its Sparrows Point, Md., plant, a new rod and wire mill. In the wire-drawing department each block is individually driven by a 20-hp. direct-current motor with control gear for any speed between the limits of 50 and 150 r.p.m.

A feature of these wire-drawing blocks is the safety device incorporated in each machine. Located on a corner of the machine, in line with the die, is a metal ring about 8 in. in diameter, supported on an arm, hinged so as to throw backwards toward the die block. Connected to this hinged arm is a switch that opens or closes the motor circuit, depending upon its position. In operation the rod or wire is threaded through this ring, then through

the drawing die and on to the drawing block. Should a snarl or a kink occur in the rod or wire as it leaves the paying roll, it is intended that it will catch on the ring, throw it back, open the motor circuit, thereby stop the motor, thus preventing accident to the machine or operator. (G. W. A. Richardson, *Wire and Wire Products*, vol. 2, no. 6, June, 1927, pp. 109–192 and 212–213, illustr., *d*)

SPECIAL MACHINERY

Photoelectric Cells

In the Burt cell the sodium is introduced directly through the glass by electrolysis. This is accomplished in the following manner. The cell, which resembles an incandescent lamp, Fig. 7, whose

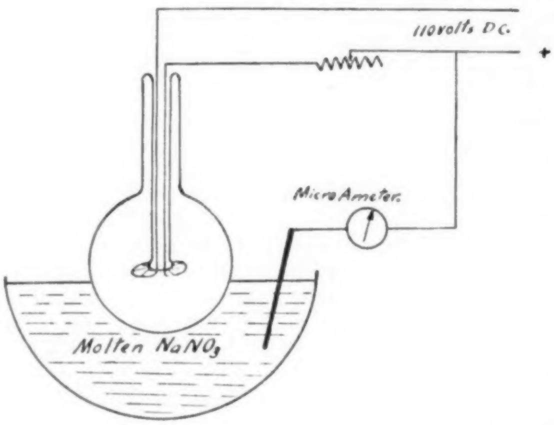


Fig. 7 Method of Manufacture of the Burt Photoelectric Cell

filament serves as a piston electrode, is dipped in a bath of molten sodium nitrate. The filament is lighted and a potential is applied between the molten mass and the filament. The electrons emitted by the filament neutralize the sodium ions of the glass forming atoms which fill the glass bulb with pure sodium vapor. The sodium ions of the glass are replaced by those of the molten salt, while NO_3 is liberated at the positive electrode. The advantage of constructing the cell in this manner is that the sensitive layer is exceedingly pure. The cell is evacuated to a very high degree and no inert gas is used. The original article gives characteristic curves of four cells and it is found that the Burt cell is more sensitive at the lower portion of the curve, giving a considerable increase in photoelectric current for a small increase in potential. Furthermore, in this cell, when it is operated above the saturation point of its characteristic curves (which is at about 100 volts), small fluctuations of voltage will not affect the current. This cell is particularly adopted for use with high light intensities and can be employed to give large currents without danger of blowing.

The article also reports some tests on one of the recent barium cells developed by the Case Research Laboratories for use in connection with talking moving pictures. This cell was found to be extremely sensitive and gave far greater currents for a given illumination and voltage than any of the cells tested. (D. Ramadanoff and W. E. Meserve, Instructors in Electrical Engineering at Cornell University. *Sibley Journal of Engineering*, vol. 41, no. 6, June, 1927, pp. 176, 194 and 196, 2 figs., *dce*)

TESTING AND MEASUREMENTS

Microcharacter Measurement of Hardness

In the present instrument *scratch* hardness is measured, a sapphire point being moved under a fixed pressure of 3 gr. over a highly polished surface of the material to be tested. The width of the cut is a linear function of the depth and a second-power function of the cross-sectional area. Therefore, measuring the width gives a means for assigning a numerical value to this characteristic. The original article shows a microscope equipped with a microcharacter and a millimicrometer ocular which has supported in its focal plane a fine scale on a transparent screen.

The scale of micro hardness is substantially the same as the Brinell, the values being multiplied by a large constant in order to keep them greater than one. The microcharacter was originally developed by the Special Committee on Bearing Metals of The American Society of Mechanical Engineers with C. H. Bierbaum as chairman. (Wallace W. Boone and Zola G. Deutsch (Mem. A.S. M.E.) American Radiator Co., Detroit, Mich., in *The Metal Industry* (New York), vol. 25, no. 6, June, 1927, pp. 248, 4 figs., *d*)

VARIA

Improved Ring for Chains or Slings

In manufacturing plants handling heavy material by cranes or hoists the load is usually lifted on a chain or wire-rope sling, having an enlarged link or ring which is placed over the crane or hoist hook. As this ring bears the whole load it must be of ample strength, and because of its large diameter it requires a larger cross-section than the rest of the sling. It is customary to make such rings of refined bar iron on account of its welding properties and because of a belief that it will bend to a noticeable extent before breaking. Many failures occur, however, under loads which are considered safe, either through failure of the weld or of the metal in the ring itself.

A type of ring which is said to be more dependable as there is no cross weld, consists of a bundle of wires knitted together. Such a ring (patent applied for by the Baldwin Locomotive Works) is made by winding many turns of wire on a spool to form a blank of proper size. The blank is then thoroughly heated and is formed between dies under a powerful hammer or press. This forming operation causes the wire to fill the voids between the turns and it will not unwind under strain. The original article shows specimens which have been tested to destruction. (*Baldwin Locomotives*, vol. 6, no. 1, July, 1927, pp. 24–25, *d*)

WELDING

Fatigue of Welds

In this case tension and fatigue tests were made on welds executed by various processes and with various kinds of welding rods. In welds it was found that all failures occurred outside the weld (1 in. from the weld); it can therefore be said that no advantage in tensile strength is shown by either the Norway iron, low-carbon steel, vanadium steel, or chrome-molybdenum filler rods when welding this type of tubing. The location of the fracture is evidently due to softening of the tube by the heat of the welding torch and the increased cross-section of the weld by the piling up of the deposited metal.

The endurance limits of the articles tested proved to have been dependent not only on the character of the filler rod but on other conditions. Some specimens showed very low endurance limits because of poor welding, and in fact the author himself says that this set of tests is valuable in demonstrating what may be expected from a poorly made weld in regard to resistance to repeated stresses. It should be particularly noted, however, that the tensile strength of this poor weld was as good as the other welds and the fracture did not occur in the weld. Evidently the tensile test was unsuccessful in detecting the deficiency in the weld whereas the fatigue test was particularly sensitive to this defect and demonstrated its existence very clearly. From some of the tests the author concludes that in so far as the deposited metal itself is concerned, the process of depositing or casting the metal by the gas method does not have any detrimental effect upon the resistance to repeated stresses.

In arc welds poor fusion was observed in a number of cases. The specimens made from the metal deposited by the arc process gave a tensile strength of 62,500 lb. per sq. in. and 1.5 per cent elongation, which means high in strength but very brittle. The endurance limit was 24,000 lb. per sq. in. or the same as with the gas weld. The electrically deposited metal evidently was not quite as resistant to failure by fatigue as the gas-deposited metal.

The automatic hydrogen process gave welds with a tensile strength of 50,400 lb. per sq. in. which is less than any of the other 1-in. diameter welded tubes. The failures occurred $1^3/_4$ in. from the weld. This method of welding evidently softened the tube more

than either the gas or arc method. The endurance limit was 16,000 lb.

One of the drawbacks of the general acceptance of welding has been a feeling among engineers that the metal deposited under such conditions possessed some undesirable property akin to brittleness which would determine its ultimate failure if long subjected to repeated stresses. The writer made a special effort to obtain some data upon the action of welded metal under a very large number of repetitions of stress to determine whether a metal solidifying under these conditions really possessed such a property as an endurance limit similar to that found in wrought ferrous metals. It was found that the deposited metal does not have an endurance limit just as wrought ferrous metals do. The evidence is given in figures in the original paper which show the endurance tests on the deposited gas and arc welds. The arc-welded tests are very convincing. Two tests at a stress of 24,000 lb. per sq. in. have completed over 600 million to 700 million cycles without failing. One test at 23,000 lb. per sq. in. has completed 700 million cycles without failing. All tests are still in progress. These tests demonstrate that the deposited weld metal is not inherently weak under stresses repeated an enormous number of times. The 700 million cycles of stress covered in these tests are equivalent to, and in many cases in excess of, the number of cycles encountered during the life of a machine or structure. (R. R. Moore, Chief of Physical Testing Br., Air Corps, McCook Field, Dayton, Ohio, *Journal of the American Welding Society*, vol. 6, no. 4, April, 1927, pp. 11–32, 21 figs., *e*)

Manufacture of Motor and Generator Parts by Welding

DIRECT-CURRENT machinery utilizes non-laminated metal for the exterior magnetic circuits or magnet frames. Heretofore castings were used, but castings lack electrical and mechanical uniformity and the designer was forced to plan for the poorest acceptable castings and was unable to take full advantage of the best ones.

As now made a heavy slab of steel, wide enough to match the magnet pole, thick enough to carry the magnetic flux, and of proper length, is heated and bent to a correct circle in powerful rolls in the boiler shop. If it is a closed ring, the abutting ends are welded by a hand-operated metallic arc. The feet and bolting lugs are also attached by arc welding. Each bearing bracket is made of pieces cut from flat plate of correct thickness and welded in place along the edges from both sides. Bolting lugs of round stock laid against flat plate automatically form proper V-notches for welding. They are made long enough so that the fillets at the two sides develop in shear the full strength of the assembly or foundation bolt. Full-size tests have demonstrated the strength of these connections.

This completes the fabrication of the frame. The machine shop then mills and registers the abutting surfaces, drills and fits the assembly bolts, turns the inside diameter, and drills necessary holes to attach the magnet cores and windings.

Base plates for General Electric machinery have seldom been made to take all the operating stresses. Purchasers have always been notified that such plates were designed to give the necessary location, level, and alignment of the component parts, and to transmit the working loads to a suitable and massive foundation. Consequently, when studying alternative base-plate designs in steel, it was unnecessary to provide a large mass of metal to absorb the vibration and shocks of operation. The requirements have been met by standard H-beams, copied to fit at the ends, and fillet-welded by the metallic arc at all abutting edges. Web and bearing plates are freely used to bridge the gaps between beam flanges, lugs, pads, and chairs welded on at any desired point. Necessary holes for attaching the machinery are drilled to close dimension, but it is ordinarily unnecessary to do any other machine work—bearing surfaces are assembled to close tolerances before welding, and the heat of the arc have proved insufficient to cause appreciable distortion.

Similar methods have been applied to the production of bearing brackets for alternating-current generators, particularly low-speed alternators. In these the combination of low speed and high output require a rotor of very large diameter. For one installation a weight of about 350 tons has to be carried at the center of a 40-ft. span. In the past a series of cast-iron or cast-steel brackets would be provided to carry this load; the modern method is to use structural steel girders built up by arc welding.

A single plate is cut for the web, and two others for top and bottom flanges. They are placed in proper position, each to each, and bolted up tightly through a few lugs tack-welded on for erection purposes. A heavy fillet weld is then run down each edge of the web, using an automatic straight-line arc welder. The end corners of the web are trimmed into a circle, and a bent extension of the upper flange welded in place. This gives a neat finish, and provides the necessary column at the end reaction. Appropriate web stiffeners, which are nothing but straight pieces of narrow plate, fitting between top and bottom flanges, are fixed in place by a corner weld run all around.

An idea of the size of this work may be gained from the dimensions of the girders for the generators to be installed in Alabama. The web is a single 2-in. plate, 6 ft. high by 40 ft. long. Top and bottom flanges are $2^{1}/_{2}$ in. thick, about 24 in. wide. Two girders are provided for each generator; at the center a housing for the upper bearing is placed between them, supported by the webs. This housing is a huge cellular box, almost cubical in shape. It is made entirely of heavy plate, joined together by hand welding. It not only carries the entire load of the rotating members, but also stiffens and braces the two girders, making them act as a unit.

Such a radical change in design of the main bearing supports, from a series of cast-iron brackets equally spaced around the circle to a pair of heavy cross girders, is associated with an equally radical change in the design of the supporting stator frame, if only to care for the fewer but larger concentrated loads.

A stator frame is merely a cylindrical shell or wrapper surrounding a number of rib-like rings, to the inner circumference of which are welded bars for attaching the laminations and electrical windings.

The construction is simple. The shell plate is cut, necessary openings for ventilation made, and rolled to the correct curve. The rings are assembled by segments (having been cut from plate by an automatic cutting blowpipe) butt-welded end to end and then edge-welded to the wrapper. Up to the limits of shipping clearances, the frame would ordinarily be a single piece: larger diameters would of course be jointed. Reinforcing bars, special struts, and lifting bars are welded between the rings at appropriate places and reinforced lugs for foundation bolts attached where necessary. The main frame is thus assembled in steel plate at surprising speed. The entire job is finished, it is emphasized in about the time it would take to make a pattern for the foundry.

Almost all of the cutting operations are performed by oxygen blowpipes automatically guided along correct lines and motor-driven at correct speeds. The blowpipes use commercially pure oxygen. Since most of the structural elements are appointed by straight lines and circular curves, the cutting shop is equipped with a number of radial guiding devices and straight-line cutting machines. Good square edges are produced with these machines equal in smoothness to the work done by a powerful hack-saw. An accuracy of less than $^{1}/_{32}$ in. is reported.

Much welding is also done by hand. A good supply of workmen is insured by maintaining a school for welders. The work is proving quite attractive to an intelligent body of men. About two months' training is required to give the necessary manual skill to make sound, clean joints of uniform appearance in heavy steel plate, erected in any position, and with the minimum of mechanical aids. During this training period the student receives no wages; instruction, however, is entirely free. Upon graduation from this welding school, the student is ready to perform numerous welding operations, under personal supervision of the foreman. (*The Iron Age*, vol. 119, no. 26, June 30, 1927, pp. 1881–1884, illustr., *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are:

ARCHIBALD BLACK, *Aeronautic Division*
H. W. BROOKS, *Fuels Division*
R. L. DAUGHERTY *Hydraulic Division*
JAMES A. HALL, *Machine-Shop Practice Division*
CHARLES W. BEESE, *Management Division*
G. E. HAGEMANN, *Materials Handling Division*
J. L. WALSH, *National Defense Division*
L. H. MORRISON, *Oil and Gas Power Division*
W. R. ECKERT, *Petroleum Division*
F. M. GIBSON and W. M. KEENAN, *Power Division*
WINFIELD S. HUSON, *Printing Machinery Division*
MARION B. RICHARDSON, *Railroad Division*
JAMES W. COX, JR., *Textile Division*
WM. BRAID WHITE, *Wood Industries Division*

Fuels

Coke-Recovery Methods[1]

F-17 A member of the Society wishes to know if any of the readers of Mechanical Engineering have attempted to recover coke from ashes, or if they know what progress has been made in this work or the perfection of equipment to effect the recovery of combustible materials.

(*a*) The coke separator about to be described is a comparatively recently developed device which is successfully recovering, from heretofore discarded ashes, from 20 to 30 per cent of high-class combustible fuel.

The separation of the good fuel from the refuse is accomplished by the flotation method, made possible by the difference in specific gravity of the two substances to be separated. In a fluid mixture having a specific gravity of about 1.28, coke and ordinary bituminous coal will float, whereas rock, clinkers, and other heavier substances will sink.

In operation cinders are dumped from cars, or other containers, into a hopper from which they are elevated to a dumping point situated directly above a revolving screen. Perforations of the proper size screen out the ashes and other material below $\frac{5}{8}$ in. Excessively large lumps of clinker also are carried over the screen, and the fine ashes and clinkers are diverted through a chute to a refuse car located underneath the structure. The remaining material, including the good fuel, is delivered to a separator containing a mixture of clay and water of 1.28 specific gravity. This may be varied if found desirable, but it has been determined that for ordinary locomotive cinders best results are obtained at 1.28.

In the separator are two screw conveyors, one taking the coke and coal which floats on the top of the solution and delivering it to a chute through which it is conveyed to a coke car located on the track alongside of the plant, while the other screw conveyor, being situated so as to take material from the bottom of the separator mixture, receives clinkers, rock, and heavy substances and delivers them to a separate chute through which they are conveyed to the refuse car.

The capacity of one type of machine is about eight tons intake material per hour, and at average locations 25 per cent of this may be recovered and returned to the fuel bins, for burning in boiler plants.

The clay used in making the mixture may be any ordinary blue or yellow clay loam, and it is hoisted in a simple contractor's elevator and wheelbarrow to an overhead platform from which it may be delivered direct to the mixing tank of 1000 gal. capacity. (D. E. White, Contracting Engr., Roberts & Schaefer Co., Chicago, Ill.)

(*b*) The writer's company manufactures, under Weber patents, a machine for separating coke from ashes in which the separation is effected in a moving stream of water which carries the lighter material (coke) further than it does the heavier material (clinker). Suitable conveyors remove each material after separation. The raw ashes are screened so as to remove $+3\frac{1}{2}$-in. material and the $-\frac{3}{8}$-in. material. The remaining product ($-3\frac{1}{2}$ in. $+\frac{3}{8}$ in.) is a mixture of coke and clinker which is fed to the machine. No foreign substance is used to increase the specific gravity of the water, and not over a barrel of new water is added per day. Once per week the machine is emptied and refilled to get rid of the dust which was washed off in the tank. Proper regulation of the speed of the water controls the B.t.u. content of the coke, which can easily be kept at 10,000 or more. The cost of operation, excluding amortization of the plant, varies from twenty-five cents to one dollar per ton of coke recovered, depending on the size of the plant. The Interborough Rapid Transit Company is using one of these machines at its 59th St. and 10th Ave. plant in New York City, and is recovering about 35 tons of coke per day from a total daily coal consumption of about 1000 tons. (R. S. Woodward, Jr., President, C. W. Hunt Co., Inc., New York, N. Y.)

Oil and Gas Power

High-Speed Oil Engine Development Problems

OG-4 What are the outstanding problems to be overcome in the development of an efficient light-weight, high-speed oil engine?

(*a*) The one outstanding problem is that of combustion. The general problem of the mechanical design of the engine has already been solved in connection with the construction of other internal-combustion engines for similar use, but of course the problem of the design of some minor details will have to be solved in the case of any individual engine. (J. W. A., New York, N. Y.)

(*b*) The outstanding problems in the development of a successful engine of this type appear to the writer to be as follows:

1 Coördinated design of combustion chamber, fuel pump and spray valve to produce a homogeneous spray in the time available. Rapid and complete combustion must be obtained with minimum excess air. This problem received considerable attention at the Oil Power Conference at Pennsylvania State College, April 21 to 23, 1927, also at the Oil and Gas Power session at the recent Spring Meeting of the Society at White Sulphur Springs, W. Va.

2 Fabricating with sufficient accuracy the vital components of the fuel pump and spray valve.

3 The selection of suitable light-weight materials for pistons, cylinders, and cylinder heads to withstand high temperatures combined with high pressures. (Edgar J. Kates, Consulting Engineer, New York, N. Y.)

The Oil Engine in the Automotive Field

OG-5 What appears to be the future of the oil engine in the automotive field, especially for large buses?

The oil engine is already a serious competitor of the carbureting engine in several branches of the automotive field in Europe. For rail cars, and of course for locomotives, no other type of engine is seriously thought of. Also, there are a number of tractors using

[1] This subject has been discussed in a previous issue.

oil engines successfully in Germany, Sweden, and probably in other countries.

For aeronautical work the Beardmore oil engine in England and the Junkers oil engine in Germany seem to be approaching practical success. It is understood that Beardmore oil engines are specified for at least one of the two giant rigid dirigibles now being constructed for service between England and India.

For bus and coach service the oil engine is regarded as of great importance. The margin of profit in such work is often close, and the fuel expense is a very heavy item. By the use of oil engines it may be possible to save two-thirds of tne fuel expense, and this in many cases means turning a loss into a profit. Already there are engines available for this type of service. Such are the M.A.N., the Deutz, the Benz, etc., and the Bosch Company has acquired the rights to manufacture the so-called Acro system of heavy fuel injection, which also seems to be a success.

As for trucks, the M.A.N. works are said to have run no less than fifteen experimental trucks very successfully on oil engines. The drivers handle the trucks easily. There is no reason why the oil engine should not be used with considerable economical advantage in this field.

As for passenger cars, it is of course uncertain how soon the oil engine will be seriously considered. Commercial concerns can buy their fuels in bulk and provide storage facilities if they recognize an economical advantage in so doing. The owner of the average passenger car wishes to pick up this fuel in small quantities. An efficient distribution service for gasoline exists now, and gasoline is a clean fuel to handle. Oil is somewhat messy, and to organize a general distribution service for it is a huge enterprise. Some oil concerns may even be hostile to the idea. The oil engine therefore may spread into the passenger field only if its performance is spectacularly above that of the gasoline engine in some respects other than that of mere economy. This would at least appear true in America. Abroad the situation may be different. (C. A. Norman, Professor, Ohio State University and Foreign Editor of *Automotive Abstracts*, Columbus, Ohio.)

Power

Electric Boilers in Industry[2]

P-3 How successful in operation in industry has been the electric boiler?

Regarding this subject as discussed by Dudley P. Craig in the June, 1927, issue of Mechanical Engineering, the writer would point out that the answer is correct only for conditions that existed three or four years ago, when P. H. Falter, who is mentioned in the discussion, was vice-president of the Electric Furnace Construction Company. Since that time extensive studies have been made with the "Kaelin" type of electric steam boiler, developed by F. T. Kaelin, chief engineer of the Shawinigan Water & Power Company. Boilers of this type are in successful operation in sizes up to 42,000 kw., corresponding to an evaporation of 65 tons of water to steam per hour, and the total installation is now over 800,000 kw.

It will be realized from this that while the industry is new it is well developed commercially, and a correctly designed boiler is just as certain in operation as an electric motor or a turbine. Thermal efficiencies run as high as 96 to 98 per cent, so there is little room left for improvement.

Regarding the possibility of formation of hydrogen or other gases, this is entirely a question of current density on the electrodes, and this at no time, in a well-designed boiler, approaches within one-fiftieth of the current density necessary to generate gas.

In the writer's opinion, Mr. Craig's statement that the 1926 E.M.F. Year Book gives 16 manufacturers of electric steam boilers should be qualified. Fourteen of these make only small immersion-type water heaters for household and similar purposes, and of the other two, the Kaelin type comprises 98 per cent of the present installations.

Electric boilers are very simple in operation. The height of water in the tank controls both the power input and the amount of steam produced. Admission of water can be made automatic, and one man can look after a battery of several boilers. There are no moving parts, and the electrodes, which are the only parts subjected to wear, are good for one to three years and can be renewed in a few hours for an insignificant cost.

It may be of interest to know that the International Paper Company at Gatineau Point now has three 42,000-kw. and one 21,000-kw. Kaelin-type electric steam boilers installed. At the present time power is available to run but one 42,000-kw. unit supplying steam to two paper machines, but as more power becomes available the remainder of the installation will be put into operation. Operation in conjunction with a steam accumulator allows a constant load on the electric boilers, with a variable load on the paper machines.

The first of the International Paper Company's Kaelin-type electric boilers was installed at their Niagara Falls plant some four years ago. This boiler was of 6000-kw. capacity. The subsequent larger installations at Gatineau Point should satisfactorily answer the question as to whether or not the electric boiler has proved successful. (Frank Hodson, Consulting Metallurgist, Philadelphia, Pa.)

[2] This subject has been discussed in a previous issue.

Questions to Which Answers Are Solicited

Railroad

R-9 What kind of grinding stone should be used for finishing piston rods, valve stems, crank pins and axle journals? Does the kind of steel from which these locomotive parts are made make any difference in the selection of a grinding stone?

R-10 What machine tool has the greatest influence or effect on the production of a locomotive machine shop (back shop)? Does a similar condition exist in a steel car shop from the standpoint of a single type or kind of machine tool?

R-11 The automobile manufacturers asked the railroads some time ago to furnish automobile cars with 12-ft. side-door openings. It is reported that both the railroads and car builders have objected to having more than a 10-ft. side-door opening, due to the fact that a wide opening makes a weak body structure. Why can't the superstructure be strengthened so as to allow a 12-ft. side-door opening?

Correspondence

Contributions to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

The Design of Motor-Bus Bodies

To the Editor:

L. C. Josephs in his paper upon this subject in the Mid-May number of Mechanical Engineering remarked that most engineers liked to reduce matters of strength to a system of formulas and added that it was doubtful that any such results would be arrived at in the design of motor-bus bodies. I believe that he is quite right in this statement and my belief is strengthened by the study of data taken from deflection and deformation tests of two bus bodies. I had the good fortune to make these tests myself and hope to describe them fully at some future date. Mr. Josephs evidently had in mind the accurate predetermination of the stresses in all the parts of the bus body. It seems to me that there is a possibility of applying mathematics to bus-body design with the idea of deriving some general rules of design rather than with the idea of accurately determining the stresses in different members of the body. The reactions between the bus body and the chassis frame seem to offer a fertile field for such investigation.

Usually the chassis frame acts as a beam supported at the wheels. The bus body rests upon this beam and extends over the rear sup-

port but does not reach the front support. If the body rests upon the chassis at the rear wheels and at its front edge only, the problem is a very simple one. The chassis bends concave upward throughout its length between the supports. The bus body also bends slightly concave upward due to the passenger load in it; but, as Mr. Josephs points out, the bus body is so much more stiff than the chassis frame that its curvature is a great deal less than that of the frame. Thus the vertical distance between the chassis frame and the body near the center of the body is greater when the body is loaded than when it is empty. For various reasons designers usually want the bus body fastened to the chassis frame at several points along each side of the bus. It seems to me the main reason is that they want the chassis to supply strength to the weak points of the body, such as the weakness caused by the presence of a door. These multple supports tend to hold the chassis frame at a constant distance from the body and since this distance tends to be greater at the center of the body than at its ends some of the fastenings between the body and the chassis frame must be in tension. I have found in a test on a double-deck bus that one of these tension reactions (upward upon the chassis and downward upon the body) was about equal to the entire passenger load. A general analysis of these reactions can be made and some rules formulated in the following manner.

The problem is simplified greatly if we assume that the stiffness of the chassis frame is the same at all cross-sections and that the bus body is absolutely rigid. The test data, which I have, indicate that the large bending moments and reactions occur near the front of the bus body and are influenced a great deal more by the spacing of the first three reaction points than by the spacing of the reaction points at the center and rear of the bus body. We are mainly interested therefore in determining the influence that changes in the lengths of the first three spaces have upon the reactions between the bus body and the chassis frame. Let us define the first span as the distance between the front axle and the front of the bus body; the second span, the distance from the front of the bus body and the first outrigger; and the third span, the distance between the first two outriggers. Let us assume also that the bus body is intimately fastened to the chassis frame from the second outrigger to the rear of the bus. This assumption will tend to increase the effect on the reactions of variations in the length of the first three spans in such a way that the general rules of design which we obtain will be on the side of safety. The ordinary method of analyzing continuous beams can be applied to the chassis frame and the following general rules deduced.

1 The bending moment in the chassis frame at the front of the bus body is equal to the vertical road reactions at the front wheels multiplied by the first span.

2 The bending moment in the chassis frame at the first outrigger does not exceed one-half the bending moment at the front of the bus body and will be opposite in sign to it.

3 The bending moment in the chassis frame at the second outrigger is not greater than one-sixth the bending moment at the front of the bus body and has the same sign.

4 The reaction at the front of the bus body is compression and is large when the third span is greater than the second span and less than the first. When all three spans are equal this reaction is two and one-third times the vertical road reaction at the front wheels.

5 The reaction at the first outrigger is tension and is large when the first span is greater than the second or third. When all three spans are equal this reaction is two and one-sixth times the vertical road reaction at the front wheels.

It is readily seen that the reactions described by rules four and five are much greater than usually assumed. The bus body should be designed to withstand them. These rules should be modified slightly when applied to certain buses (particularly single-deck buses) which carry some of the passenger load directly upon the chassis frame. Such buses are designed so that the floor of the body rests directly upon the chassis frame. Part of the passenger load can be considered as a uniform load applied directly to the chassis frame. This uniform load will modify the bending moments in the chassis frame and the reactions between the frame and the bus body. The modification is on the side of danger. The bending moments in the chassis frame at both the first and second outriggers and the reaction at the first outriggers are increased arithmetically. The reaction at the front of the bus body is decreased.

I hope these views will have some small influence in focusing the attention of the bus-body designers upon the possibility of applying, in a general way, the ordinary engineering formulas to bus-body design.

Charles B. Norris.[1]

Grand Rapids, Mich.

Diesel Engine for Air Service

To the Editor:

In his article on the Light Supercharged Diesel Engine for Air Service, appearing in the July issue of Mechanical Engineering, Mr. Sperry speaks about obtaining 300 lb. per sq. in. m.e.p., but if this is done at the expense of a very great amount of weight it would not be very useful. I do not not see anything in the paper regarding the engine speed at which this power plant could be operated. We are running our engines at 2500 r.p.m. direct drive with a fuel consumption at full throttle as low as 0.48 lb. per b.hp. Is it possible to operate the Diesel type of engine referred to in the paper at such speeds, and if not what speeds can it be operated at which will bring it up to a sufficient output per cubic inch to be comparable with the gasoline four-cycle engine? Some idea as to the frontal area of the engine to be compared with one of our 450-hp. water-cooled or air-cooled gasoline engines would be of great interest. Also some comparison as to the size of the radiator as determined by the loss of head to the water jackets would be of value.

From our meager knowledge of the situation we have and others have come to the conclusion that the advantages of the Diesel engine are not sufficient to overcome the great advantage of the abovementioned fuel economy at high engine speeds. The elimination of simple ignition systems and carburetor systems used today have been overbalanced by the introduction of pumps, injector valves, and increased weight of the Diesel engine. Some figures of the possibilities which might be expected from the Diesel type in direct comparison with some modern 450-hp. engine other than a purely thermodynamic basis, or a general discussion of the means of overcoming the usual difficulties in the Diesel engine would give the engineer a better picture of the problem.

Arthur Nutt.[2]

Buffalo, N. Y.

The Term "Heat Cycle"

To the Editor:

In accordance with the wish of Mr. Reynolds, as expressed by his letter in Mechanical Engineering for June, 1927, we offer the following suggestions:

1 That on page 643 of the *Transactions* of 1923, and on page 1420 of Mechanical Engineering for December, 1926, the titles be changed by eliminating the word "Heat" before Cycle, or else substituting the phrase "Vapor Cycle" for "Heat Cycle"

2 That the term "Heat Balance," even though it is often misused and is not always satisfactory, does not permit the substitution of "Heat Cycle" for it

3 That in general, such statements as "The main turbines will be bled in order to complete the heat cycle," would be far better eliminated, or else modified so as to read in some such manner as, "The main turbines will be bled in order *to save fuel, to improve the station economy*, or *to increase the plant thermal efficiency*."

Frank O. Ellenwood.[3]

Ithaca, N. Y.

[The attention of the reader is called to other correspondence on this subject published in June, 1927, issue of Mechanical Engineering, p. 693, Editor.]

[1] Mechanical Engineer, Haskelite Manufacturing Corporation. Mem. A.S.M.E.

[2] Chief Engineer, Motor Division, Curtiss Aeroplane & Motor Co., Inc.

[3] Professor, Heat-Power Engineering, Cornell University. Mem. A.S.M.E.

Engineering and Industrial Standardization

Mathematical Symbols

THE FIRST proposed standard to reach the sponsors for the Sectional Committee on Scientific and Engineering Symbols and Abbreviations is that on Mathematical Symbols. This proposal was prepared by Sub-Committee No. 6 of which Dr. Edward V. Huntington, Professor of Mechanics, Harvard University, is Chairman.

It will be recalled that in January, 1926, this Sectional Committee was organized under the procedure of the American Engineering Standards Committee as the culmination of a series of efforts on the part of the A.S.C.E., A.S.T.M., A.I.E.E., S.P.E.E., A.S.M.E., and other national organizations. The societies which accepted joint sponsorship are the A.A.A.S., A.S.C.E., A.I.E.E., S.P.E.E., and the A.S.M.E. Twenty-nine national societies and associations have appointed official representatives on the Sectional Committee which is headed by Dr. J. Franklin Meyer of the Bureau of Standards, as Chairman, Dr. Sanford A. Moss, Thomson Research Laboratory, as Vice-Chairman, and Mr. Preston S. Millar of the Electrical Testing Laboratories, as Secretary.

This proposed standard for Mathematical Symbols having been approved by a unanimous vote of the Sectional Committee is now before the five sponsor societies for approval and submission to the A.E.S.C. for approval and designation as an American Standard. Accordingly, as one step in the A.S.M.E. consideration of the standard it is reproduced below for the information of our members and readers. Criticism and comment may be sent to Mr. C. B. LePage, Secretary of the A.S.M.E. Standardization Committee, 29 West 39th Street, New York.

MATHEMATICAL SYMBOLS[1]

1 Arithmetic and Algebra

1.1 $= \neq + - \pm \mp < > \leqq \geqq ( ) [ ] \% \infty$ ≒ (for approximately equal to).

1.2 $a \times b = a \cdot b = ab$; $a \div b = \frac{a}{b} = a/b$ (Influence extends to next + or —). Thus, $a - b/c - d$ should not be used for $(a-b)/(c-d)$. Note that $\frac{a}{b}$ is difficult to print in running text.

1.3 $a/b = c/d$ for proportion. Discourage $a:b::c:d$.

1.4 Notation by powers of 10 for very large or very small numbers is recommended; as 3.140×10^3 and 3.140×10^{-2}. The notation $0.0^5\,314$ is useful in tables, to indicate that there are five zeroes after the decimal point.

1.5 In writing numbers having a large number of digits, half-spaces instead of commas should be used to separate groups of digits. In writing decimals, the 0 before the decimal point should not be omitted (except in tables).

1.6 $|x|$ = absolute value of x. $x! = 1.2.3\ldots x$. Discourage $\underline{x}|$.

1.7 $\sqrt{x} = +\sqrt{x}$, not $\pm\sqrt{x}$ (x being real and positive). $a^{1/n} = \sqrt[n]{a}$. $a^{-n} = 1/a^n$. $\exp x = e^x$ is useful when x is a complicated expression. Note that the bar or vinculum after the $\surd$ is very expensive to print.

1.8 When $\log x$ is ambiguous, use $\log_{10} x$ or $\log_e x$. The notation $\ln x$ may be mentioned as an alternative for $\log_e x$.

1.9 $P(n, r) = n(n-1)(n-2)\ldots(n-r+1)$; $C(n, r) = [n(n-1)(n-2)\ldots(n-r+1)]/[1.2.3\ldots r]$ = binomial coefficients. A common alternative for $C(n, r)$ is $\binom{n}{r}$; this, however, is difficult to print in running text.

1.10 $a \propto b$ (meaning a varies directly as b).

[1] Note: The recommendations concerning terms and symbols in elementary mathematics contained in Chapter 8, pages 74–85 of the Report on the Re-Organization of Mathematics in Secondary Education, made in 1923 by the National Committee on Mathematical Requirements (under the auspices of the Mathematical Association of America), were, with one or two unimportant exceptions, endorsed by Sub-Committee No. 6.

2 Elementary Geometry

2.1 $\angle$ $\triangle$ $\parallel$ $\perp$ $\odot$ $\square$ $\therefore$

3 Analytic Geometry

3.1 x, y, z; ξ, η, ζ; rectangular coördinates. Right-handed system preferred.

3.2 ρ, s = intrinsic coördinates. ρ = radius of curvature, s = length of arc.

3.3 $l = \cos\alpha$, $m = \cos\beta$, $n = \cos\gamma$, direction cosines.

3.4 r, θ = polar coördinates. ψ = angle from radius vector to tangent.

3.5 r, θ, ϕ = spherical coördinates. θ = co-latitude, ϕ = longitude. (Usage general in mathematical physics; other notations are used in astronomy.)

3.6 r, θ, z = cylindrical coördinates. (Usage diverse.)

3.7 Conics: e = eccentricity. p = semi-latus rectum (usage general in U. S.).

3.8 Straight line: $y = mx + b$.

4 Trigonometric and Hyperbolic Functions

4.1 $° \; ' \; ''$ $\sin x$, $\cos x$, $\tan x$, $\operatorname{ctn} x$, $\sec x$, $\csc x$.

4.2 $\sin^{-1}x$ = the principal value of the angle whose sine is x (when x is real). Thus, $-\pi/2 \leqq \sin^{-1}x \leqq \pi/2$, $0 \leqq \cos^{-1}x \leqq \pi$, $-\pi/2 \leqq \tan^{-1}x \leqq \pi/2$. (Discourage arc sin x.)

4.3 $\sin^2 x$ for $(\sin x)^2$ is an exceptional notation, justified by usage.

4.4 $\sinh x$, $\cosh x$, $\tanh x$, $\operatorname{ctnh} x$, $\operatorname{sech} x$, $\operatorname{csch} x$.

4.5 $\cosh^{-1}x$ = the principal value (when x is real). (Discourage arc sinh x).

4.6 $\sinh^2 x$ for $(\sinh x)^2$ is an exceptional notation, justified by usage.

4.7 In general, f^{-1} means the inverse of the function f; while f^2 denotes iteration of the functional operation. But in exceptional cases, f^2 may denote the square of the function f (as in $\sin^2 x$ and $\sinh^2 x$). In general, $[f(x)]^{-1} = 1/f(x)$.

5 Calculus

5.1 If $y = f(x)$, derivative $= y' = f'(x) = \frac{dy}{dx} = D_x y$. Second derivative $y'' = f''(x) = \frac{d(y')}{dx} = D_x^2 y = \frac{d^2y}{dx^2}$. Note $\frac{d^2y}{dx^2}$ cannot be regarded as a fraction, exception when x is the independent variable; in general, $\frac{d^2}{dx^2} = D_x^2$ = a symbol of operation on y.

5.2 If $u = f(x,y)$, partial derivative $= u_x = f_x(x,y) = D_x u = \frac{\partial u}{\partial x}$. Similarly, $u_{xy} = f_{xy}(x,y) = D_y(D_x u) = \frac{\partial^2 u}{\partial y \partial x}$. Note; $\frac{\partial^2 u}{\partial y \partial x}$ and $\frac{\partial u}{\partial x}$ are not fractions; $\frac{\partial}{\partial x} = D_x$ and $\frac{\partial^2}{\partial y \partial x} = D_y D_x$ are symbols of operation.

5.3 Δy = increment, dy = differential. δy = variation, $\sum_{i=a}^{b}$ = summation.

5.4 $\dot{x} = dx/dt = v$; $\ddot{x} = dv/dt$ (used only for differentiation with respect to the time t, and difficult to print).

5.5 $\lim_{x \to a} (y) = b$; $y \to b$ as $x \to a$. (Discourage $\doteq$)

5.6 $\int_b^a f(x)dx$. $F(x) \Big/_b^a = F(b) - F(a)$ $\int\int f(x)dxdy = \int[\int f(x,y)dx]dy$.

5.7 $\pi = 3.1416\ldots$ $e = 2.718\ldots$ $i = \sqrt{-1}$ (in pure mathematics).

5.8 If $z = x + iy$, then $|z|$ = absolute value, or magnitude, $\angle z$ = angle, $R(z)$ and $I(z)$ = real and imaginary parts, $\bar{z}$ = conjugate of z. (Where $\bar{z}$ is difficult to print, use conj. z.)

6 Special Functions

6.1 Bessel functions. The notation used in G. N. Watson's

Treatise, 1922, as endorsed by E. P. Adams in the Smithsonian Tables, 1922, is recommended.

6.2 Bernoulli numbers. Of the five or six different notations in use, the notation B_1, B_3, B_5, ... has historical priority and many practical advantages, but the notation B_1, B_2, B_3, ... is the one most used in recent years. To indicate what usage is being followed, authors will do well to state explicitly the value of the first few numbers, as $B_1 = 1/6, B_2 = 1/30, B_3 = 1/42, \ldots$

6.3 $\gamma = 0.5772\ldots$ (Euler's constant).

7 Vector Analysis

7.1 Vectors to be indicated in printed matter by letters in bold-face type, and in written manuscript by letters modified by a bar above (or by the doubling of some part of the character). The magnitude of a vector to be indicated in print by the corresponding italic letter, and in manuscript (when necessary) by the use of the absolute value signs, $|\ |$.

7.2 The scalar product, or dot product, $= a \cdot b$, the dot being centered. (Other notations are Sab, or (ab) in round parentheses.)

7.3 The vector product, or cross product, $= a \times b$, the cross being small. (Other notations are Vab, or $[ab]$ in square brackets.)

7.4 i, j, k = unit vectors along the axes (right-handed system).

7.5 As to further questions of notation in Vector Analysis (including Tensor Analysis), the Sub-Committee recognizes the desirability of a thorough-going attempt to bring uniformity out of the present diversity of usage, but recommends the appointment of a special committee to take up this subject.

8 Abbreviations

8.1 It is desirable to distinguish between (1) a "symbol," that is, a single letter or a single letter affected with subscripts, etc., which is to be used to represent a numerical value in a formula; and (2) an "abbreviation," which may consist of several letters, but is not intended to be substituted for a numerical quantity in a formula.

8.2 Standard abbreviations such as ft./sec^2., ft-lb./min., etc., should not be further condensed, lest clearness be sacrificed to brevity.

National American Standard for Fire-Hose-Coupling Screw Threads

SINCE March 1 two states have been added to the list of those which have passed compulsory legislation relative to the use of the National American Standard $2^1/_2$-inch fire-hose-coupling screw thread. The State of Texas recently appropriated \$5000 a year for two years to provide a fund which will be used in the conversion of the fire-hose-coupling screw threads of its present equipment to the National American Standard. Sets of conversion tools have been purchased already and we are informed that the work is in progress under the supervision of the Engineering Department of the State Fire Insurance Commission.

(Continued on page 936)

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 548 to 552 inclusive, as formulated at the meeting of May 20, 1927, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

Case No. 548

Inquiry: Is it permissible to insert a tee connection between a superheater and its safety valve to permit withdrawal of steam for soot blowers, provided the boiler proper is equipped with its full complement of safety valves according to Code requirements? It is pointed out that Pars. P-277 and P-290 refer to boiler and not to superheater outlets.

Reply: It is the opinion of the Committee that Par. P-277, with the exception of the last sentence, and Par. P-290 apply only to the main safety valves on the boiler proper, and therefore the insertion of a tee connection between the superheater and its safety valve to permit of withdrawal of steam, as outlined, does not conflict with the Code requirements.

Case No. 549

Inquiry: Is it the intent of Par. P-260 and Fig. P-16 of the Code that elliptical manholes must be inserted in the shells of boilers or drums always with the long axis thereof at right angles to the longitudinal center line of the shell? Will it not be permissible on boiler shells and drums not exceeding 48 in. in diameter to insert an elliptical manhole with the long axis parallel to the longitudinal center line of the shell, so that less depth of flange is required at the center?

Reply: There is nothing in the Code to specify the direction of the long axis of elliptical manholes. It is the opinion of the Committee that such manholes, when inserted in the shells of boilers or drums, may be placed in either direction provided the opening is properly reinforced with reference to the long axis of the manhole.

Case No. 550

Inquiry: Is it necessary under the requirements of Par. P-333 that portable boilers of any type must be fitted with the additional or duplicate stamping on a non-ferrous plate 3 in. by 4 in. in size, as specified in section *c* of that paragraph? It is pointed out that often other types of boilers are fitted out for portable use, such as those covered by items *d* and *h* of Par. P-333.

Reply: It is the opinion of the Committee that the provision in the last sentence of Par. P-333*c* was intended to cover portable boilers of any type, whether of locomotive, vertical-tubular, Scotch marine, or other types that may be adaptable for portable use. If such a boiler is built for stationary use and is subsequently placed in portable service, it is incumbent upon those responsible for the change to see that the requirement for additional or duplicate stamping on the non-ferrous plate is complied with.

Case No. 551

(In the hands of the Committee)

Case No. 552

Inquiry: Is it necessary in purchasing base metal plate for welded steel low-pressure heating boilers, to specify firebox quality for plates that are to be exposed to the products of combustion, or is any good soft grade of steel acceptable for this purpose?

Reply: Pars. H-74 to H-77 are intended to cover steel plate of either flange or firebox quality, the chemical and physical requirements to be in accordance with Pars. H-74 and H-76. In all other respects the steel should conform to the Specifications for Steel Boiler Plate, Pars. S-5 to S-17 of Section II of the Code. Such material is practically the same as that covered by the Specifications for Steel Plate of Flange Quality for Forge Welding, Pars. U-110 to U-125 of Section VIII of the Code, and it is the intention of the Committee to revise Par. H-74 to conform to Par. U-70 of Section VIII of the Code. Pars. U-112 and U-115 have already been revised to permit the use of two grades of material, Grade A being the same as before and Grade B permitting a maximum carbon content of 0.20 per cent and a corresponding minimum tensile strength of 50,000 lb. per sq. in.

Cast-Iron Pipe Flanges and Flanged Fittings

Tentative American Standards for Maximum Working Saturated Steam Pressures of 125 and 250 Lb. per Sq. In. (Gage)

IN THE Spring of 1921 when the unification and extension of the flanged and screwed-fitting standards in force in this country seemed desirable, the American Engineering Standards Committee authorized the organization of a Sectional Committee on the Standardization of Pipe Flanges and Fittings. The sponsor organizations designated for this project are the Heating and Piping Contractors National Association, the Manufacturers' Standardization Society of Valve and Fittings Industry and The American Society of Mechanical Engineers.

The review of these standards was assigned to its Sub-Committee No. 1 and after a thorough study this Committee made its report to the Sectional Committee, who discussed the report at its meetings and finally passed it by letter ballot of the entire Committee. It was then submitted to the three sponsor organizations for approval and transmission to the American Engineering Standards Committee. The A.S.M.E. Standardization Committee is now, therefore, called upon to make recommendations to the Council concerning this standard. Copies of these proposed standards in page-proof form are now available and may be procured by addressing C. B. LePage, Assistant Secretary, A.S.M.E., 29 West 39th St., New York, N. Y.

Below are given the introductory notes from the 250-lb. pressure standard and Tables 1, 2, 4, and 5. The tables which are omitted are entitled as follows: Table 3, Dimensions and Theoretical Weights (Pounds) of Screwed Companion and Blind Flanges; Table 6, Dimensions of Reducing Tees and Reducing Crosses (Short Body Patterns); Table 7, Dimensions of Laterals, Reducers, True Y's (Straight Sizes); Table 8, Dimensions of Reducing Laterals (Short Body Pattern); Table 9, Dimensions of Base Elbows and Base Tees; Table 10, Dimensions of Anchorage Bases for Tees (Straight Sizes); Table 11, Dimensions of Anchorage Bases for Reducing Tees; Table 12, Theoretical Weights in Pounds of Elbows, Crosses, Tees, Side-Outlet Tees, and Laterals; Table 13, Theoretical Weights, in Pounds of Reducing Elbows, Reducers, and Eccentric Reducers; Table 14, Theoretical Weights in Pounds of Reducing Laterals; Table 15, Theoretical Weights in Pounds of Reducing Tees; Table 16, Theoretical Weights in Pounds of Reducing Crosses.

The introductory notes to the 125-lb. pressure standard are omitted as they are practically identical with the 250-lb. standard. Tables 2, 4, and 5 are reproduced herewith. The titles of the tables omitted are similar to the ones given in the foregoing paragraph for the 250-lb. standard.

250-Lb. Cast-Iron Flanged Fittings

Introductory Notes

Sizes. The sizes of the fittings in the following tables will be identified by the corresponding "nominal pipe size." This nominal pipe size is the same as the port diameter of fittings for pipe having inside diameters of 12 in. and smaller. For pipe 14 in. and larger the corresponding O.D. of the pipe is given, and consequently the fittings will have a smaller port diameter.

Pressure Rating. It is recommended that in addition to the maximum working steam pressure for which these fittings are intended, the sizes 8 in. and smaller may also be used for maximum non-shock working hydraulic pressure of 325 lb. per sq. in. (gage) at a temperature of 250 deg. fahr., and for maximum non-shock working hydraulic pressure of 400 lb. per sq. in. at or near the ordinary range of air temperatures.

TABLE 1 PHYSICAL AND CHEMICAL REQUIREMENTS OF CAST IRON FOR FITTINGS

Casting	Tensile strength in lb. per sq. in. Minimum	Per cent sulphur (Not over)
Light[1]	18,000	0.10
Medium[3]	21,000	0.10
Heavy[2]	24,000	0.12

[1] Note: Light castings are those having any section less than 1/2 in. thickness.
[2] Note: Heavy castings are those in which no section is less than 2 in. in thickness.
[3] Note: Medium castings are those not included in either of the above classes.

TABLE 2 TEMPLATES FOR DRILLING FOR 250-LB. STANDARD CAST-IRON PIPE FLANGES

Nominal pipe size	Diameter of flange	Thickness of flange[3,6] (Min.)	Diameter of raised face	Diameter of bolt circle	Number of bolts[1]	Diameter of bolts	Diameter of drilled bolt holes[1]	Length of bolts[2,4]	Length of bolt studs with 2 nuts[4]	Total effective area bolt metal	Stress lb. per sq. in. bolt metal[5]	Size of ring gasket
1	4 7/8	11/16	2	3 1/2	4	5/8	3/4	2	..	0.808	970	1 × 2 7/8
1 1/4	5 1/4	3/4	2 1/2	3 7/8	4	5/8	3/4	2 1/4	..	0.808	1520	1 1/4 × 3 1/4
1 1/2	6 1/8	13/16	2 7/8	4 1/2	4	3/4	7/8	2 1/2	..	1.208	1345	1 1/2 × 3 3/4
2	6 1/2	7/8	3 5/8	5	8	5/8	3/4	2 1/2	..	1.616	1595	2 × 4 3/8
2 1/2	7 1/2	1	4 1/8	5 7/8	8	3/4	7/8	3	..	2.416	2090	2 1/2 × 5 1/8
3	8 1/4	1 1/8	5	6 5/8	8	3/4	7/8	3 1/4	..	2.416	2030	3 × 5 7/8
3 1/2	9	1 3/16	5 1/2	7 1/4	8	3/4	7/8	3 1/4	..	2.416	2460	3 1/2 × 6 1/2
4	10	1 1/4	6 3/16	7 7/8	8	3/4	7/8	3 1/2	..	2.416	3120	4 × 7 1/8
5	11	1 3/8	7 5/16	9 1/4	8	3/4	7/8	3 3/4	..	2.416	4385	5 × 8 1/2
6	12 1/2	1 7/16	8 1/2	10 5/8	12	3/4	7/8	3 3/4	..	3.624	3915	6 × 9 7/8
8	15	1 5/8	10 5/8	13	12	7/8	1	4 1/4	..	5.04	4400	8 × 12 1/8
10	17 1/2	1 7/8	12 3/4	15 1/4	16	1	1 1/8	5	..	8.80	3625	10 × 14 1/4
12	20 1/2	2	15	17 3/4	16	1 1/8	1 1/4	5 1/4	..	11.10	3975	12 × 16 5/8
14 O.D.	23	2 1/8	16 1/4	20 1/4	20	1 1/8	1 1/4	5 1/2	..	13.88	3735	13 1/4 × 19 1/8
16 O.D.	25 1/2	2 1/4	18 1/2	22 1/2	20	1 1/4	1 3/8	6	..	17.86	2255	15 1/4 × 21 1/4
18 O.D.	28	2 3/8	21	24 3/4	24	1 1/4	1 3/8	6 1/4	..	21.43	4505	17 × 23 1/2
20 O.D.	30 1/2	2 1/2	23	27	24	1 1/4	1 3/8	6 1/2	..	21.43	4845	19 × 25 3/4
24 O.D.	36	2 3/4	27 1/4	32	24	1 1/2	1 5/8	7 1/2	9 1/2	31.08	4500	23 × 30 1/2
30 O.D.	43	3	37 3/16	39 1/4	28	1 3/4	2	8 1/4	10 1/2	48.89	5590	29 × 37 1/2
36 O.D.	50	3 3/8	43 15/16	46	32	2	2 1/4	9 1/4	11 1/2	73.70	5355	......
42 O.D.	57	3 11/16	50 11/16	52 3/4	36	2	2 1/4	9 3/4	12	82.90	5945	......
48 O.D.	65	4	58 9/16	60 3/4	40	2	2 1/4	10 1/2	13	92.08	7315	......

All dimensions given in inches.

[1] Note: Drilling templates are in multiples of four, so that fittings may be made to face in any quarter, and bolt holes straddle the center line. For bolts smaller than 1 3/4 in. the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal diameter of the bolt. Holes for bolts 1 1/8 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

[2] Note: The bolt holes on cast-iron flanged fittings are not spot-faced for ordinary service. When required, the fittings and flanges in sizes 36 in. and larger can be spot-faced or back-faced, so that standard length bolts can be used.

[3] Note: All 250-lb. cast-iron standard flanges have a 1/16-in. raised face. This raised face is included in the face-to-face, center-to-face, and the minimum thickness of flange dimensions.

[4] Note: Bolts shall be of steel with standard "Rough Square Heads" and the nuts shall be of steel with standard "Rough Hexagonal" dimensions; all as given in the "Tentative American Standard on Wrench Head Bolts and Nuts, and Wrench Openings." For bolts 1 3/4 in. diameter and larger, bolt-studs with a nut on each end are recommended. Hexagonal nuts for pipe sizes 1 in. to 16 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 18 in. to 48 in. can be conveniently pulled up with box wrenches.

[5] Note: The stress shown is that of internal pressure only assumed to act on a circular area equal in diameter to the outside diameter of the raised face.

[6] Note: For tongue-groove and male-female facings it is recommended that the dimensions given in Table 5 of the Tentative American Standards for Steel Pipe Flanges and Flanged Fittings be used.

Marking. All fittings must have marks cast on them indicating the manufacturer and the figures 250 indicating the maximum working steam pressure for which the fittings are intended.

Material. The dimensional standards for cast-iron fittings covered herein are based on a high-grade product equal to that given in A.S.T.M. Specification No. A-48-18 suitable for the maximum temperature and pressure for which the standard is designed. It is strongly recommended that the material for such service be in accordance with the latest revision of A.S.T.M. Specification No. A-48. The physical and chemical requirements of these flanges and fittings shall be in accordance with Table 1, which requirements are taken from A.S.T.M. Specification No. A-48-18.

Facing. All 250-lb. cast-iron flanges and flanged fittings shall have a raised face 1/16 in. high of the diameters given in Table 2. The raised face is included in the minimum flange thickness and center-to-face dimensions.

An inspection limit of plus or minus 1/32 in. shall be allowed on all center-to-contact-surface dimensions for sizes up to and including 10 in. and plus or minus 1/16 in. on sizes larger than 10 in. An inspection limit of plus or minus 1/16 in. shall be allowed on all contact-surface-to-contact-surface dimensions for sizes up to and including 10 in. and plus or minus 1/8 in. on sizes larger than 10 inches.

Bolting. Drilling templates are in multiples of four, so that fittings may be made to face in any quarter.

Bolt holes shall straddle the center line. For bolts smaller than 1 3/4 in. the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal size of the bolt. Holes for bolts 1 3/4 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

TABLE 4 DIMENSIONS OF ELBOWS

Nominal pipe size	Inside diameter of fitting port	Center to face elbow[1,2,3,4] (A)	Center to face long-radius elbow (B)[1]	Center to face 45-deg. elbow[1,3] (C)	Diameter of flange	Thickness of flange[1] (minimum)	Diameter raised face[1]	Metal thickness of body (minimum)
1	1	4	5	2	$4\frac{7}{8}$	$\frac{11}{16}$	2	$\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{1}{4}$	$4\frac{1}{4}$	$5\frac{1}{2}$	$2\frac{1}{2}$	$5\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{2}$	$\frac{1}{2}$
$1\frac{1}{2}$	$1\frac{1}{2}$	$4\frac{1}{2}$	6	$2\frac{3}{4}$	$6\frac{1}{8}$	$\frac{13}{16}$	$2\frac{7}{8}$	$\frac{1}{2}$
2	2	5	$6\frac{1}{2}$	3	$6\frac{1}{2}$	$\frac{7}{8}$	$3\frac{5}{8}$	$\frac{1}{2}$
$2\frac{1}{2}$	$2\frac{1}{2}$	$5\frac{1}{2}$	7	$3\frac{1}{2}$	$7\frac{1}{2}$	1	$4\frac{1}{8}$	$\frac{9}{16}$
3	3	6	$7\frac{3}{4}$	$3\frac{1}{2}$	$8\frac{1}{4}$	$1\frac{1}{8}$	5	$\frac{9}{16}$
$3\frac{1}{2}$	$3\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$	4	9	$1\frac{3}{16}$	$5\frac{1}{2}$	$\frac{9}{16}$
4	4	7	9	$4\frac{1}{2}$	10	$1\frac{1}{4}$	$6\frac{3}{16}$	$\frac{5}{8}$
5	5	8	$10\frac{1}{4}$	5	11	$1\frac{3}{8}$	$7\frac{5}{16}$	$\frac{11}{16}$
6	6	$8\frac{1}{2}$	$11\frac{1}{2}$	$5\frac{1}{2}$	$12\frac{1}{2}$	$1\frac{7}{16}$	$8\frac{1}{2}$	$\frac{3}{4}$
8	8	10	14	6	15	$1\frac{5}{8}$	$10\frac{5}{8}$	$\frac{13}{16}$
10	10	$11\frac{1}{2}$	$16\frac{1}{2}$	7	$17\frac{1}{2}$	$1\frac{7}{8}$	$12\frac{3}{4}$	$\frac{15}{16}$
12	12	13	19	8	$20\frac{1}{2}$	2	15	1
14 O.D.	$13\frac{1}{4}$	15	$21\frac{1}{2}$	$8\frac{1}{2}$	23	$2\frac{1}{8}$	$16\frac{1}{4}$	$1\frac{1}{8}$
16 O.D.	$15\frac{1}{4}$	$16\frac{1}{2}$	24	$9\frac{1}{2}$	$25\frac{1}{2}$	$2\frac{1}{4}$	$18\frac{1}{2}$	$1\frac{1}{4}$
18 O.D.	17	18	$26\frac{1}{2}$	10	28	$2\frac{3}{8}$	21	$1\frac{3}{8}$
20 O.D.	19	$19\frac{1}{2}$	29	$10\frac{1}{2}$	$30\frac{1}{2}$	$2\frac{1}{2}$	23	$1\frac{1}{2}$
24 O.D.	23	$22\frac{1}{2}$	34	12	36	$2\frac{3}{4}$	$27\frac{1}{4}$	$1\frac{5}{8}$
30 O.D.	29	$27\frac{1}{2}$	$41\frac{1}{2}$	15	43	3	$37\frac{5}{16}$	2

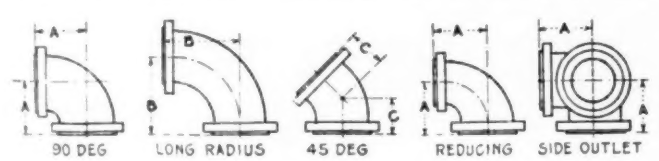
All dimensions given in inches.

[1] NOTE: All 250-lb. cast-iron standard flanges have a $\frac{1}{16}$-in. raised face. This raised face is included in the face-to-face, center-to-face, and the minimum-thickness-of-flange dimensions.

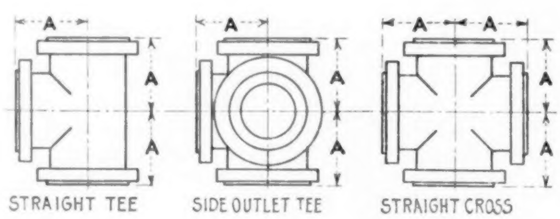
[2] NOTE: Reducing elbows and side-outlet elbows carry the same dimensions center-to-face as straight-size elbows corresponding to the size of the largero pening.

[3] NOTE: Special-degree elbows ranging from 1 to 45 deg. inclusive, have the same center-to-face dimensions given for 45-deg. elbows, and those over 45 deg. and up to 90 deg. inclusive shall have the same center-to-face dimensions given for 90-deg. elbows. The angle designation of an elbow is its deflection from straight-line flow and is also the angle between the flange faces.

[4] NOTE: Side-outlet elbows shall have all openings on intersecting centerlines.



SKETCH TO ACCOMPANY TABLE 4 OF 250-LB. FITTINGS



SKETCH TO ACCOMPANY TABLE 5 OF 250-LB. FITTINGS

TABLE 5 DIMENSIONS OF TEES AND CROSSES (STRAIGHT SIZES)

Nominal pipe size[2]	Inside diameter of fitting port	Center to face tees and crosses[1,2,3] (A)	Face to face tees and crosses[1,2,3] (AA)	Diameter of flange	Thickness of flange[1] (minimum)	Diameter of raised face[1]	Metal thickness of body (minimum)
1	1	4	8	$4\frac{7}{8}$	$\frac{11}{16}$	2	$\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{1}{4}$	$4\frac{1}{4}$	$8\frac{1}{2}$	$5\frac{1}{4}$	$\frac{3}{4}$	$2\frac{1}{2}$	$\frac{1}{2}$
$1\frac{1}{2}$	$1\frac{1}{2}$	$4\frac{1}{2}$	9	$6\frac{1}{8}$	$\frac{13}{16}$	$2\frac{7}{8}$	$\frac{1}{2}$
2	2	5	10	$6\frac{1}{2}$	$\frac{7}{8}$	$3\frac{5}{8}$	$\frac{1}{2}$
$2\frac{1}{2}$	$2\frac{1}{2}$	$5\frac{1}{2}$	11	$7\frac{1}{2}$	1	$4\frac{1}{8}$	$\frac{9}{16}$
3	3	6	12	$8\frac{1}{4}$	$1\frac{1}{8}$	5	$\frac{9}{16}$
$3\frac{1}{2}$	$3\frac{1}{2}$	$6\frac{1}{2}$	13	9	$1\frac{3}{16}$	$5\frac{1}{2}$	$\frac{9}{16}$
4	4	7	14	10	$1\frac{1}{4}$	$6\frac{3}{16}$	$\frac{5}{8}$
5	5	8	16	11	$1\frac{3}{8}$	$7\frac{5}{16}$	$\frac{11}{16}$
6	6	$8\frac{1}{2}$	17	$12\frac{1}{2}$	$1\frac{7}{16}$	$8\frac{1}{2}$	$\frac{3}{4}$
8	8	10	20	15	$1\frac{5}{8}$	$10\frac{5}{8}$	$\frac{13}{16}$
10	10	$11\frac{1}{2}$	23	$17\frac{1}{2}$	$1\frac{7}{8}$	$12\frac{3}{4}$	$\frac{15}{16}$
12	12	13	26	$20\frac{1}{2}$	2	15	1
14 O.D.	$13\frac{1}{4}$	15	30	23	$2\frac{1}{8}$	$16\frac{1}{4}$	$1\frac{1}{8}$
16 O.D.	$15\frac{1}{4}$	$16\frac{1}{2}$	33	$25\frac{1}{2}$	$2\frac{1}{4}$	$18\frac{1}{2}$	$1\frac{1}{4}$
18 O.D.	17	18	36	28	$2\frac{3}{8}$	21	$1\frac{3}{8}$
20 O.D.	19	$19\frac{1}{2}$	39	$30\frac{1}{2}$	$2\frac{1}{2}$	23	$1\frac{1}{2}$
24 O.D.	23	$22\frac{1}{2}$	45	36	$2\frac{3}{4}$	$27\frac{1}{4}$	$1\frac{5}{8}$
30 O.D.	29	$27\frac{1}{2}$	55	43	3	$37\frac{5}{16}$	2

All dimensions given in inches.

[1] NOTE: All 250-lb. cast-iron standard flanges have a $\frac{1}{16}$-in. raised face. This raised face is included in the face-to-face, center-to-face, and the minimum-thickness-of-flange dimensions.

[2] NOTE: Tees, side-outlet tees, and crosses, 16 in. and smaller, reducing on the outlet, have the same dimensions center-to-face, and face-to-face as straight-size fittings, corresponding to the size of the larger opening. Sizes 18 in. and larger, reducing on the outlet, are made in two lengths, depending on the size of the outlet as given in Table 6 of the complete code.

[3] NOTE: Tees and crosses, reducing on run only, carry same dimensions center-to-face and face-to-face as straight-size fittings corresponding to size of the larger opening.

Bolts shall be of steel with standard "Rough Square Heads" and the nuts shall be of steel with standard "Rough Hexagonal" dimensions; all as given in the Tentative American Standard on Wrench Head Bolts and Nuts and Wrench Openings. For bolts, $1\frac{3}{4}$ in. in diameter and larger, bolt-studs with a nut on each end are recommended.

Hexagonal nuts for pipe sizes 1 in. to 16 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 18 in. to 48 in. can be conveniently pulled up with box wrenches.

Spot Facing. The bolt holes of 250-lb. cast-iron flanged fittings and flanges shall not be spot-faced for ordinary service. When required, the fittings and flanges in sizes 36 in. and larger may be spot-faced or back-faced to the minimum thickness of flanges with a plus tolerance of $\frac{1}{8}$ in.

Reducing Fittings. Reducing elbows and side-outlet elbows carry same dimensions center to face as straight-size elbows corresponding to the size of the larger opening.

Tees, side-outlet tees, crosses, and laterals sizes 16 in. and smaller reducing on the outlet or branch, have the same dimension, center-to-face, and face-to-face as straight-size fittings corresponding to the size of the larger opening. Sizes 18 in. and larger, reducing on the outlet or branch, are made in two lengths depending on size of outlet as given in the tables of dimensions.

Tees, crosses, and laterals, reducing on the run only, have the same dimensions center-to-face, and face-to-face as straight-size fittings corresponding to the size of the larger opening.

Reducers and eccentric reducers for all reductions have the same face-to-face dimensions for larger opening as given in Table 7 of complete code.

Reducing fittings listed in this standard shall be ordered by designation of outlets in their proper sequence, indicated in sketches on p. 5 of complete standard.

Special double-branch elbows whether straight or reducing have the same dimensions center-to-face as straight-size elbows corresponding to the size of the larger opening.

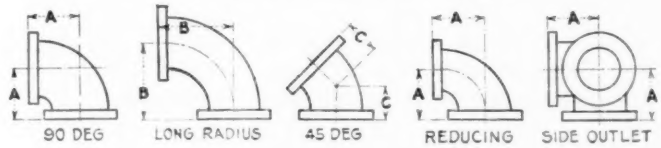
Side-outlet elbows and side-outlet tees shall have all openings on intersecting center lines.

Elbows. Special-degree elbows ranging from 1 to 45 deg. inclusive have the same center-to-face dimensions given for 45 deg. elbows and those over 45 deg. and up to 90 deg. inclusive shall have the same center-to-face dimensions given for 90 deg. elbows. The angle designation of an elbow is its deflection from straight-line flow and is the angle between the flange faces.

True Y's. The dimensions of true Y's, straight sizes, are given in Table 6 of the complete code. Other forms are considered special and should be made to suit conditions.

Laterals. Laterals (Y-Branches) both straight and reducing sizes 8 in. and larger shall be reinforced to compensate for the inherent weakness in the casting design.

125-Lb. Cast-Iron Fittings



SKETCH TO ACCOMPANY TABLE 4 OF 125-LB. FITTINGS

TABLE 4 DIMENSIONS OF ELBOWS

Nominal pipe size[1]	Center to face elbow[2,3,4] (A)	Center to face long-radius elbow[2,3,4] (B)	Center to face 45-deg. elbow[3] (C)	Diameter of flange	Thickness of flange (minimum)	Metal thickness of body (minimum)
1	$3\frac{1}{2}$	5	$1\frac{3}{4}$	$4\frac{1}{4}$	$\frac{7}{16}$	$\frac{7}{16}$
$1\frac{1}{4}$	$3\frac{3}{4}$	$5\frac{1}{2}$	2	$4\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{16}$
$1\frac{1}{2}$	4	6	$2\frac{1}{4}$	5	$\frac{9}{16}$	$\frac{7}{16}$
2	$4\frac{1}{2}$	$6\frac{1}{2}$	$2\frac{1}{2}$	6	$\frac{5}{8}$	$\frac{7}{16}$
$2\frac{1}{2}$	5	7	3	7	$\frac{11}{16}$	$\frac{7}{16}$
3	$5\frac{1}{2}$	$7\frac{3}{4}$	3	$7\frac{1}{2}$	$\frac{3}{4}$	$\frac{7}{16}$
$3\frac{1}{2}$	6	$8\frac{1}{2}$	$3\frac{1}{2}$	$8\frac{1}{2}$	$\frac{13}{16}$	$\frac{7}{16}$
4	$6\frac{1}{2}$	9	4	9	$\frac{15}{16}$	$\frac{1}{2}$
5	$7\frac{1}{2}$	$10\frac{1}{4}$	$4\frac{1}{2}$	10	$\frac{15}{16}$	$\frac{1}{2}$
6	8	$11\frac{1}{2}$	5	11	1	$\frac{9}{16}$
8	9	14	$5\frac{1}{2}$	$13\frac{1}{2}$	$1\frac{1}{8}$	$\frac{5}{8}$
10	11	$16\frac{1}{2}$	$6\frac{1}{2}$	16	$1\frac{3}{16}$	$\frac{3}{4}$
12	12	19	$7\frac{1}{2}$	19	$1\frac{1}{4}$	$\frac{13}{16}$
14	14	$21\frac{1}{2}$	$7\frac{1}{2}$	21	$1\frac{3}{8}$	$\frac{7}{8}$
16	15	24	8	$23\frac{1}{2}$	$1\frac{7}{16}$	1
18	$16\frac{1}{2}$	$26\frac{1}{2}$	$8\frac{1}{2}$	25	$1\frac{9}{16}$	$1\frac{1}{16}$
20	18	29	$9\frac{1}{2}$	$27\frac{1}{2}$	$1\frac{11}{16}$	$1\frac{1}{8}$
24	22	34	11	32	$1\frac{7}{8}$	$1\frac{1}{4}$
30	25	$41\frac{1}{2}$	15	$38\frac{3}{4}$	$2\frac{1}{8}$	$1\frac{7}{16}$
36	28	49	18	46	$2\frac{3}{8}$	$1\frac{5}{8}$
42	31	$56\frac{1}{2}$	21	53	$2\frac{5}{8}$	$1\frac{13}{16}$
48	34	64	24	$59\frac{1}{2}$	$2\frac{3}{4}$	2

All dimensions given in inches.

[1] NOTE: Size of all fittings listed indicates nominal inside diameter of port.

[2] NOTE: Reducing elbows and side-outlet elbows carry same dimensions center-to-face as straight-size elbows, corresponding to the size of the larger opening.

[3] NOTE: Special-degree elbows, ranging from 1 to 45 deg. inclusive, have the same center-to-face dimensions given for 45-deg. elbows and those over 45 deg. and up to 90 deg. inclusive shall have the same center-to-face dimensions given for 90-deg. elbows. The angle designation of an elbow is its deflection from straight-line flow and is also the angle between the flange faces.

[4] NOTE: Side-outlet elbows shall have all openings on interescting centerlines.

TABLE 2 TEMPLATES FOR DRILLING FOR 125-LB. STANDARD CAST-IRON PIPE FLANGES

Nominal pipe size	Diameter of flange	Thickness of flange[3] (minimum)	Diameter of bolt circle	Number of bolts[1]	Diameter of bolts	Diameter of drilled bolt holes[1]	Length of bolts[2]	Length of bolt-stud with two nuts[4]	Total effective area bolt metal	Stress lb. per sq. in. bolt metal[5]	Size of ring gasket
1	4 1/4	7/16	3 1/8	4	1/2	5/8	1 1/2	..	0.504	1340	1 × 2 5/8
1 1/4	4 5/8	1/2	3 1/2	4	1/2	5/8	1 1/2	..	0.504	1755	1 1/4 × 3
1 1/2	5	9/16	3 7/8	4	1/2	5/8	1 3/4	..	0.504	2215	1 1/2 × 3 3/8
2	6	5/8	4 3/4	4	5/8	3/4	2	..	0.808	2065	2 × 4 1/8
2 1/2	7	11/16	5 1/2	4	5/8	3/4	2 1/4	..	0.808	2885	2 1/2 × 4 7/8
3	7 1/2	3/4	6	4	5/8	3/4	2 1/4	..	0.808	3510	3 × 5 3/8
3 1/2	8 1/2	13/16	7	8	5/8	3/4	2 1/2	..	1.616	2410	3 1/2 × 6 3/8
4	9	15/16	7 1/2	8	5/8	3/4	2 3/4	..	1.616	2870	4 × 6 7/8
5	10	15/16	8 1/2	8	3/4	7/8	2 3/4	..	2.416	2440	5 × 7 3/4
6	11	1	9 1/2	8	3/4	7/8	3	..	2.416	3110	6 × 8 3/4
8	13 1/2	1 1/8	11 3/4	8	3/4	7/8	3 1/4	..	2.416	4915	8 × 11
10	16	1 3/16	14 1/4	12	7/8	1	3 1/2	..	5.04	3485	10 × 13 3/8
12	19	1 1/4	17	12	7/8	1	3 1/2	..	5.04	5065	12 × 16 1/8
14	21	1 3/8	18 3/4	12	1	1 1/8	4	..	6.60	4685	14 × 17 3/4
16	23 1/2	1 7/16	21 1/4	16	1	1 1/8	4	..	8.80	4575	16 × 20 1/4
18	25	1 9/16	22 3/4	16	1 1/8	1 1/4	4 1/2	..	11.10	4135	18 × 21 5/8
20	27 1/2	1 11/16	25	20	1 1/8	1 1/4	4 3/4	..	13.88	4030	20 × 23 7/8
24	32	1 7/8	29 1/2	20	1 1/4	1 3/8	5 1/4	..	17.86	4385	24 × 28 1/4
30	38 3/4	2 1/8	36	28	1 1/4	1 3/8	5 3/4	..	25.00	4700	30 × 34 5/8
36	46	2 3/8	42 3/4	32	1 1/2	1 5/8	6 1/2	..	41.41	4035	36 × 41 1/4
42	53	2 5/8	49 1/2	36	1 1/2	1 5/8	7 1/4	9 1/2	46.57	4810	42 × 47 7/8
48	59 1/2	2 3/4	56	44	1 1/2	1 5/8	7 1/2	9 1/2	56.93	5200	48 × 54 3/8
54	66 1/4	3	62 3/4	44	1 3/4	2	8 1/4	10 1/2	76.82	4755	54 × 61
60	73	3 1/8	69 1/4	52	1 3/4	2	8 1/2	11	90.79	4925	60 × 67 1/2
72	86 1/2	3 1/2	82 1/2	60	1 3/4	2	9 1/2	12	104.70	6150	72 × 80 5/8
84	99 3/4	3 7/8	95 1/2	64	2	2 1/4	10 1/2	13	147.33	5825	84 × 93 1/2
96	113 1/4	4 1/4	108 1/2	68	2 1/4	2 1/2	11 1/2	14 1/2	205.56	5415	96 × 106 1/4

All dimensions given in inches.

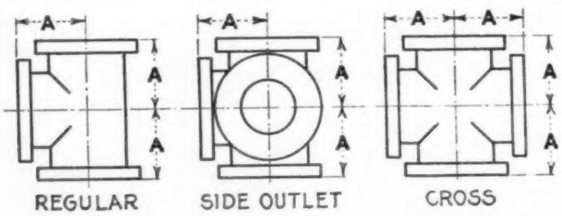
[1] Note: Drilling templates are in multiples of four, so that fittings may be made to face in any quarter, and bolt holes straddle the centerline. For bolts smaller than 1 3/4 in. the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal diameter of the bolt. Holes for bolts 1 3/4 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

[2] Note: The bolt holes on cast-iron flanged fittings are not faced for ordinary service. When required, the fittings and flanges in sizes 36 in. and larger can be spot-faced or back-faced, so that standard-length bolts can be used.

[3] Note: All 125-lb. cast-iron standard flanges have a plain face.

[4] Note: Bolts shall be of steel with standard "Rough Square Heads" and the nuts shall be of steel with standard "Rough Hexagonal" dimensions; all as given in the "Tentative American Standard on Wrench Head Bolts and Nuts, and Wrench Openings." For bolts 1 3/4 in. diameter and larger, bolt-studs with a nut on each end are recommended. Hexagonal nuts for pipe sizes 1 in. to 48 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 48 in. to 96 in. can be conveniently pulled up with box wrenches.

[5] Note: The stress shown is that of internal pressure only assumed to act on a circular area equal in diameter to the outside diameter of a ring gasket covering the flange to the inside of bolts.



Sketch to Accompany Table 5 of 125-Lb. Fittings

TABLE 5 DIMENSIONS OF TEES AND CROSSES (STRAIGHT SIZES)

Nominal pipe sizes[1,2]	Center to face tees and crosses[2,3] (A)	Face to face tees and crosses[2,3] (AA)	Diameter of flange	Thickness of flange (minimum)	Metal thickness of body (minimum)
1	3 1/2	7	4 1/4	7/16	7/16
1 1/4	3 3/4	7 1/2	4 5/8	1/2	7/16
1 1/2	4	8	5	9/16	7/16
2	4 1/2	9	6	5/8	7/16
2 1/2	5	10	7	11/16	7/16
3	5 1/2	11	7 1/2	3/4	7/16
3 1/2	6	12	8 1/2	13/16	7/16
4	6 1/2	13	9	15/16	1/2
5	7 1/2	15	10	15/16	1/2
6	8	16	11	1	9/16
8	9	18	13 1/2	1 1/8	5/8
10	11	22	16	1 3/16	3/4
12	12	24	19	1 1/4	13/16
14	14	28	21	1 3/8	7/8
16	15	30	23 1/2	1 7/16	1
18	16 1/2	33	25	1 9/16	1 1/16
20	18	36	27 1/2	1 11/16	1 1/8
24	22	44	32	1 7/8	1 1/4
30	25	50	38 3/4	2 1/8	1 7/16
36	28	56	46	2 3/8	1 5/8
42	31	62	53	2 5/8	1 13/16
48	34	68	59 1/2	2 3/4	2

All dimensions given in inches.

[1] Note: Size of all fittings listed indicates nominal inside diameter of port.

[2] Note: Tees, side-outlet tees, and crosses, 16 in. and smaller, reducing on the outlet, have the same dimensions center-to-face, and face-to-face as straight-size fittings, corresponding to the size of the larger opening. Sizes 18 in. and larger, reducing on the outlet, are made in two lengths, depending on the size of the outlet as given in Table 6.

[3] Note: Tees and crosses, reducing on run only, carry same dimensions center-to-face and face-to-face as a straight-size fitting corresponding to size of the larger opening.

Design Improvements in Panama Tugs

According to *Motorship*, July, 1927, two new 750-hp., 125-ft., Diesel tow boats in the process of construction for the Panama Canal will be the largest and most powerful boats of this type in the world. Living accommodations, it is stated, will be provided for six "gold" or American men and 24 "silver" or tropical employes. One tug, for the present, is being equipped with the latest radio equipment. Each boat is being equipped with very powerful electric towing machines, equivalent in capacity and size to that of the largest steam tugs.

Two definite steps in advancement of tow-boat design have been included in the design of the hulls; the first is the installation of bulk heads and double bottoms, enabling the tug to remain afloat with one of her main compartments bilged. The second change in design involves the cutting away of the deadwood aft and installing a simple casting in the way thereof. This is expected to improve the handling qualities of the tugs.

The main propelling machinery of each boat will be fitted with 480-hp. Diesel engines driving direct-connected, 330-kw., direct-current, 250-volt generators, and on extension shafts 50-kw. direct-current exciters. The two main generators will, operating in series, drive a double-armature, 750-hp., direct-current motor. This motor will be direct connected to a single propeller approximately 10 ft. 6 in. in diameter, which will turn at the rate of from 115–140 r.p.m. at full power. Auxiliaries will depend upon current from the exciters during operation of the main engines.

As auxiliary power each tug will be equipped with a 10-kw. generator driven by a direct-connected, 25-hp., four-cycle Diesel. An air compressor can be driven off an extension of the auxiliary generator shaft through a clutch, and an independent motor-driven compressor will be installed in each boat. Other auxiliary equipment will include motor-driven centrifugal fire pumps of 1000 gal. per minute capacity at 100-lb. per sq. in. pressure, a salvage pump, lighting equipment, ice-manufacturing machine, sanitary pumps, etc., all operating electrically from current obtained by stepping down the exciter voltage through a motor generator to 125 volts. Each tug is equipped with a second motor generator which will convert the 25-cycle, 230-volt current of the Canal Zone to 125-volt, direct-current for use during tie up periods.

Addenda to Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision in the rules in its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

Important addenda that have been suggested for insertion in the Code are published below and are submitted for criticism and comment thereon from anyone interested therein. Discussion should be mailed to C. W. Obert, Secretary to the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Boiler Code Committee for consideration.

After 30 days have elapsed following this publication, which will afford full opportunity for such criticism and comment upon the revisions as approved by the Committee, it is the intention of the Committee to present the addenda as finally agreed upon to the Council of the Society for approval as an addition to the Boiler Construction Code. Upon approval by the Council, the addenda will be published in the form of addenda data sheets, distinctly colored pink, and offered for general distribution to those interested, and included in the mailings to subscribers to the Boiler Code interpretation data sheets.

Proposed Standard Practice for Making Hydrostatic Test on a Boiler Pressure Part to Determine the Maximum Allowable Working Pressure in Accordance with Par. P-247

1 *Material.* The structure shall be made from material approved for the intended use by the A.S.M.E. Boiler Code.

2 *Workmanship.* The dimensions and minimum thickness of the structure to be tested should not vary materially from those actually used. If possible the structure to be tested should be selected at random from a quantity of such intended for use.

3 *Preparation for Test.* It is necessary to test only the weakest point of the structure but several points should be checked to make certain that the weakest one is included. The less definite the location of the weakest point, the more points should be checked.

The movement of the reference points may be measured with reference to a fixed surface, or two reference points may be located on opposite sides of a symmetrical structure and the total deformation between those two points measured.

Indicating micrometer gages accurate to 0.001 in. are most suitable for measuring deformation of the structure at the reference points although any form of accurate micrometer may be used.

A hand test pump is satisfactory as a source of hydrostatic pressure. Either a test gage or a reliable gage which has been calibrated with a test gage should be attached to the structure.

The maximum hydrostatic pressure that must be provided for will vary from 2 to 3 times the expected maximum allowable working pressure for carbon-steel structures.

The location of the weakest point of the structure may be determined by applying a thin coating of plaster of Paris or similar material, and noting where the surface coating starts to break off under hydrostatic test. The coating should be allowed to dry before the test is started.

4 *Hydrostatic Test.* The first application of hydrostatic pressure need not be less than the expected maximum allowable working pressure. At least ten separate applications of pressure, in approximately equal increments should be made between the initial test pressure and the final test pressure.

When each increment of pressure has been applied the valve between the pump and the structure should be closed and the pressure gage watched to see that the pressure is maintained and that no leakage occurs. The total deformation at the reference points should be measured and recorded and the hydrostatic pressure recorded. The pressure should then be released and each point checked for any permanent deformation which should be recorded.

Only one application of each increment of pressure is necessary. The pressure should be increased by substantially uniform increments, and readings taken until the elastic limit of the structure has obviously been exceeded.

5 *Physical Characteristics of Metal.* The following physical qualities of the metal should be determined from test specimens if method 8*a* for determining the maximum allowable working pressure is used:

a Tensile Strength
b Proportional Limit

After the test is completed, cut out at least five tensile test coupons that can preferably be machined to standard $^1/_2$-in. diameter × 2-in. gage length specimens (Fig. S-4, Section II of the Code). These coupons should preferably be representative of the metal at the weak sections of the structure and their axes should preferably be parallel to the direction of greatest stress. These coupons must not be cut out with a gas torch as there is danger of changing the physical qualities of the material.

6 *Plotting Curves.* A single cross-section sheet should be used for each reference point of the structure. A scale of 1 in. = 0.01 in. deformation and a scale of at least 1 in. equals the approximate test pressure increments has been found satisfactory. Plot two curves for each reference point, one showing total deformation under pressure and one showing permanent deformation when the pressure is removed.

7 *Determining Proportional Limit of Pressure Part.* Locate the proportional limit on each curve of total deformation as the point at which the total deformation ceases to be proportional directly to the hydrostatic pressure. Draw a straight line that will pass through the average of the points that lie approximately in a straight line. The proportional limit will occur at the value of hydrostatic pressure where the average curve through the points deviates from this straight line.

In pressure parts such as headers where a series of similar weak points occur the average hydrostatic pressure corresponding to the proportional limits of the similar points may be used.

The proportional limit obtained from the curve of total deformation may be checked from the curve of permanent deformation by locating the point where the permanent deformation begins to increase regularly with further increases in pressure. Permanent deformations of a low order that occur prior to the point really corresponding to the proportional limit of the structure, resulting from the equalization of stresses and irregularities in the material, may be disregarded.

It should be made certain that the curves show the deformation of the structure and not slip nor displacement of reference surfaces, the gages, or the structure.

8 *Determining Maximum Allowable Working Pressure. a* Having determined the proportional limit of the weakest point of the structure the corresponding maximum allowable working pressure may be determined by the formula:

$$P = \frac{H \times S}{E \times 5}$$

P = maximum allowable working pressure
H = hydrostatic pressure at the proportional limit of the pressure part
S = average tensile strength of material
E = average proportional limit of the material.

b As an alternate method of determining the maximum allowable working pressure, eliminating the necessity of cutting coupons for tensile tests, the proportional limit of the material may be considered as $^2/_5$ of its tensile strength. The maximum allowable working pressure may then be taken as one-half of the hydrostatic pressure corresponding to the proportional limit of the pressure part.

9 *Retests.* A retest should be allowed on an additional structure if errors or irregularities are obvious in the results.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

College Men in Engineering

IT WOULD require greater editorial restraint than we possess to let pass without comment so significant an event as the matriculation into the engineering profession of the graduates of the technical schools and colleges of the country. No doubt these young men, with baccalaureate admonitions ringing in their ears and conscious of a greater knowledge than shall at any subsequent period of their lives burden their minds, will have neither the opportunity nor the inclination to give heed to another outpouring in their behalf so that our thoughts may more profitably be addressed to the men of the profession among whom these raw recruits are about to take their places.

Whatsoever may be his mental and cultural endowments, the young graduate is above all else a man at a turning point of his life, one poised on the threshold of his career, and presents to those who come in contact with him a problem and a responsibility which they may not lightly ignore. To everyone who has even the slightest imagination, this youth, who now enters the ranks of those who face life on their own, brings the vision of their own past. He represents the potentialities which they themselves once brought to the advance of civilization; he is the symbol of things once hoped for, and now, despaired of; he is one of the army of reinforcements which brings with it new strength, fresher ideals, and greater courage.

Professionally this man is come to help the advance of engineering and through it civilization. In such a role he makes the same sacrifices and faces the same rewards that have come to all engineers. Help him, therefore, for the good of the profession and give him as hearty a welcome as his sincerity deserves. Remember that his crudities are the concomitants of youth, that they are generally indicative of latent endowments, and that proper training will develop them into amiable virtues. Impetuously he may trample some of your most cherished ideas. Have patience with him; he may yet save you from your own follies.

Personally the youth will be viewed with indifference, with scorn, or with jealousy by many who might profit by the cultivation of his friendship. Are you too big a man to bother with him? Remember what a great engineer once said that in closing the door on such a youth he might shut out more than he shut in. Have you, taught in a harder school, a contempt for the college man, or have you, out of contact with your alma mater, a conviction that the "colleges have gone to the dogs?" Your conceit surpasses that which you imagine in the boy. Are you, conscious of your own limitations, afraid that the newcomer will show you up, that he will surpass you or supplant you, so that jealousy comes between you and you hinder where you should help? Make him your friend, teach him what he should know of the details of a strange job, be glad in his success, and if he goes further than you have gone, remember that perhaps the greatest achievement of your life may lie in making one of the world's most worthy engineers.

Here, in this boy, is your own lost youth. Help him to realize your thwarted ambitions; save him from the mistakes which caused your failure.

Coöperative Education

ELSEWHERE in this issue is a brief account of a meeting held at Drexel Institute, Philadelphia, of the Association of Coöperative Colleges. This group of educators, coördinators, and employee representatives made up in zeal what they may have lacked in numbers, and gave evidence of a sincerity and earnestness of purpose which is probably one of the reasons for the success of this method of education. If interest centered around the Association's president, Dr. Herman Schneider, it was because of the extraordinary personality of this pioneer in coöperative education, a man with the fervent soul of a prophet.

Among other impressions one came away with a feeling that men in industry who employed college students on the coöperative basis were favorable to the system as was shown not only by the proportion of employee representatives present but by their expressions of approval. It was gratifying to note that industry felt a sufficient responsibility in the fundamental education of men whom it would eventually assimilate, whether directly or indirectly, to give the coöperative plan its active support without narrow considerations of immediate or direct personal profit.

The growth of this system of education is evidence of its success and value. While it may have been misapplied or mismanaged, and while some institutions have tried it and given it up, there is abundant proof that certain types of institutions, favorably located with respect to industries, flourish under it and educate men who become its enthusiastic proponents. Some educators, accustomed to more academic methods, fail to appreciate the system, or give it faint-hearted support, but there is a growing group of intelligent men, who have studied coöperative education closely and who have seen the results it produces, who recognize both its advantages and its limitations and who favor its introduction wherever, and only wherever, it is perfectly adaptable.

When operating side by side with classes of all-resident students, the coöperative system brings perplexing problems of administration, some of them more imagined than real, but some of them capable of arousing violent differences of opinion. The solution of these problems is clearly urgent, but many trials will be necessary and much error will be experienced. Clear and unprejudiced thinking is greatly needed.

Machine Tools—Their Place in Our Lives

IT IS A fact that many people in this age of machines have no idea what machine tools are. It is even more surprising that many engineers have a rather hazy idea as to the importance of machine tools to their own profession and to the world in general.

This condition is in part due to the "behind the scenes" position which machine tools occupy upon the world's stage. We do not ordinarily see the highly complicated and ingenious machinery by which the remarkable stage effects of the modern theater are attained. The production itself dazzles the audience and the actors receive acclaim. Only a few know and appreciate the machines and operators behind the scenes. Neither do we usually have an opportunity to see far beyond the front office of the manufacturing plant.

Lack of general knowledge of the machines "behind the scenes" which make possible the astounding modern productions in the manufacturing field may in some measure be blamed for the retention behind the scenes of machine tools which it is just as well

the public should not see. Machine-tool design has kept pace with the most advanced engineering thought, but the willingness to adopt these advanced tools has not come about so rapidly in the minds of some plant managers—particularly those who never allow the public to peer behind the scenes in their plants.

It has remained for the machine-tool builders themselves to throw the light of publicity upon their own rapid progress in design and construction of what a past-president of The American Society of Mechanical Engineers aptly called "The Master Tools of Industry." By means of exhibitions they are demonstrating in the open what their usually hidden machines will do. These exhibitions are fostering a spirit of replacement which has been badly needed and are thereby of great value to machine-tool users as well as to the builders of the tools.

Machine tools at the most are but two steps away from the things of everyday life. Machine tools either made the machines which make the goods—as in the case of textiles, shoes, furniture, etc., or they actually make the goods directly as in the case of automobiles, sewing machines, vacuum cleaners, and even the humble safety razor and its blades.

All this will explain why The American Society of Mechanical Engineers takes an active interest in the machine-tool exhibitions which are scheduled for the coming September, and why engineers are urged to make the most of these opportunities to study the machinery which *should* be "behind the scenes" in their shops in the near future.

Fuels and Engineering Progress

In the early days the chief sources of power were man and beasts of burden, with an occasional wind or water mill. The invention of the steam engine marked the beginning of a new era, a period in which man ceased to be the source of power and became its master. The liberation of man from the arduous task of supplying much of his own power of transportation and that necessary for fashioning his implements, permitted more rapid and extensive travel, introduced a semblance of mass production, and released energy for the conception and development of still better methods.

At first, scant attention was given to efficiency in fuel-burning equipment. Good fuel was plentiful and its cost was insignificant. However, as fuel costs mounted, steps were taken to reduce the consumption, new designs of combustion equipment appeared, firing methods were studied, and improvements such as the insulation of steam lines, became general practice. Prime movers have been improved in order to squeeze the last bit of energy from the source of power. In some instances fuels are treated to recover by-products, before introduction to the furnace, that profit may be derived from their sale. More efficient methods of so treating fuels are sought on every hand. Up-graded coals from exceedingly poor sources are expected to join the procession of man's slaves in this highly mechanized age. Even new fuels are demanded to meet the needs of the day when there shall be no more of Nature's convenient supplies.

To make the most of all of this effort, however, engineers and other interested specialists must be kept in close contact with developments and opportunity given for exchange of experiences. The International Conference on Bituminous Coal, held in Pittsburgh, November 15 to 18, 1926, with a registration of 1700 delegates from thirteen different countries, indicated the wide interest in the subject, and undoubtedly aided greatly in stimulating further activity. Among the subjects discussed were coal resources, mining, transportation, synthesis of petroleum, coal-tar disposal, the practical value of research, powdered coal, power stations, coal distillation and carbonization, etc.

One of the most active groups of engineers in this field is the Fuels Division of the A.S.M.E. This group has mapped out a comprehensive research program embracing the following subjects, selected as most urgently demanding actual work:

1 The constitution of coal
2 Fuel utilization and elimination of wastes
3 The preparation of coal
4 The carbonization of coal, which would include both high- and low-temperature methods.

The First National Fuels Meeting, to be held under the auspices of the Fuels Division in St. Louis, October 10 to 13, 1927, will provide another much needed forum for users and producers of fuels. Unlike the Pittsburgh conference, however, this meeting will not be limited to bituminous coal, nor coal alone, but will embrace, among other subjects, American fuel resources; combustion and heat transfer; characteristics of boilers and stokers; application of powdered fuel; the burning of liquid fuels; power-plant problems, including air preheaters and the clinkering of coal ash, etc. Industrial furnaces also will be discussed, as will the general subject of industrial applications of heat. One problem in which there should be universal interest is the pollution of the atmosphere with products of combustion thrown off by industrial and domestic furnaces. Several cities have adopted smoke abatement methods with varying results, and a session to be devoted to this subject exclusively should prove of great value to other cities contemplating action. Although the meeting is being arranged by the Fuels Division, it will be for the benefit of all branches of the profession, and the several engineering societies of the United States interested intimately or even remotely in the use or production of fuels will be represented at it.

Just what the future holds, it is difficult to predict at this stage of the game; however, this much is reasonably sure, judging by past records: The problems will be faced squarely; they will be attacked in mass formation; they will be solved, and engineering progress and civilization will march steadily forward.

What Would You Know?

An editorial in the May, 1927, issue of Mechanical Engineering discussed the new "ask-me-another" fad and the feverish rate at which books of questions and answers are being published. Mechanical engineers should have some part in this move for a better-educated public, it was pointed out, and fourteen very interesting questions, most of which must have proved puzzlers, were presented for the readers to ponder over. It is pretty safe to assume that the majority marveled at the luck of the editor in selecting so many subjects upon which they happened to have no information at the moment, then after a brief period of head scratching, "looked in the book." Of course they may not have found the answers in any of the popular question-and-answer books, but certainly a trip to the library settled most of them to the satisfaction of the critical. "Looking in the book" in this case need not have been done sheepishly, however, for it has been wisely said that "A wise man is not he who knows everything, but he who knows where to find what he does not know."

There are, however, many questions upon which there are no published records, or if there are they are not readily available. Very often the necessity for finding the right answer puts the job in the class of anything but a parlor game. Obviously, in such instances, there should be some means of bringing together those who do not know and those who either know or can point to the place where such information may be found.

Engineers in increasing numbers are finding the Conference Table section of Mechanical Engineering a most valuable medium for establishing this contact. Examination of several issues will disclose the fact that every question represents a real desire to know something, and that in most cases the facts are not readily available in standard library works or technical papers. In some cases the subjects have proved so interesting that months after the original answer was published discussion and additional information continue to appear. Plant executives know that the conference of department heads is a valuable means for the collection and comparison of data, but the record of a conference of this nature is not available to an outsider who may have similar problems to solve. The Conference Table of Mechanical Engineering serves the same purpose, but it has the additional value of permanency. The answer to your question may not be "in the book," but if it is placed before the membership of the Society through the Conference Table it not only will be answered for your benefit, but will go "in the book" for all who encounter the problem in the future. What would you know?—Ask the Conference Table and profit not only yourself, but establish a record for others who are likely to face the same problems.

Proposed New Division of A.S.M.E. on Applied Mechanics

With various branches of mechanical engineering based upon the application of the fundamentals of mechanics, physics, and mathematics, modern industry presents many problems, the solutions of which demand the application of rigorous scientific methods. The proposed new division of the A.S.M.E. on Applied Mechanics will provide a forum for the presentation and discussion of such problems, fundamental in character, in which mathematical analyses are extensively used.

The question of organizing a Professional Division on Applied Mechanics, in The American Society of Mechanical Engineers is being considered by a group of members of the Society who met during the 1926 annual meeting. This section would embrace:

I Analytical mechanics as applied to rigid, elastic, and fluid bodies, including
- (a) Mechanics of materials
- (b) Kinematics and dynamics of machines
- (c) Stresses in structures and machines
- (d) Friction and lubrication

II Physics, including
- (a) Heat flow
- (b) Thermodynamics
- (c) Acoustic and noise problems

III Applied mathematics

Reasons for Such Organization

Some reasons for such an organization are as follows:

1 The various branches of mechanical engineering are based upon the application of the fundamentals of mechanics, physics, and mathematics. Modern industry presents many problems whose solutions demand the application of rigorous scientific methods. Among the papers given before the A.S.M.E. are many of fundamental character in which mathematical analyses are extensively used. If the above proposed division be formed, it will offer a place for the presentation of such papers where those interested may have an opportunity to discuss them. With the present arrangement, many papers of this fundamental character are read simultaneously and it is therefore impossible to hear all of them.

2 A division on Applied Mechanics will tend to stimulate the application of analysis to the solution of engineering problems and will aid in the development of research in mechanics and technical physics, which is badly needed in this country.

3 In this country there is a large gap between mathematics and engineering. Our mathematicians do not contribute much toward the solution of technical problems, and on the other hand, our engineers prefer to use empirical formulas instead of having recourse to more thorough analyses. Closer coöperation between pure and applied sciences will undoubtedly be beneficial to both branches of knowledge. The organization of a division on Applied Mechanics will undoubtedly bring about a better contact between experts in mathematics and in engineering. Furthermore, there is no division of our Society, nor any association in the United States, that is now devoted to this field.

4 The proposed division on Applied Mechanics will offer a means whereby engineers in this country can make contact with similar foreign organizations. The Third International Congress in Applied Mathematics and Mechanics that was held in Zurich in September, 1926, attracted a large number of scientists and engineers from all parts of the world. Only four representatives from the United States, however, attended this congress. This is a poor representation from this country in proportion to the importance of our educational institutions and to the magnitude of our industries. This small attendance can be explained by a lack of organization of those interested in applied science which the above division will undoubtedly provide.

Committee Appointed to Make Plan for Division

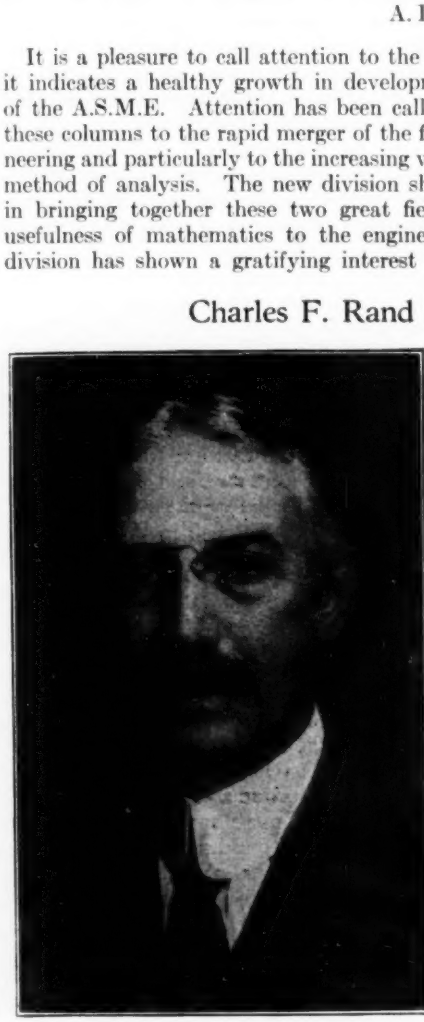
According to the announcement at the annual convention at New York, a meeting was held on December 8, in the Society's rooms to discuss the formation of such a new professional division. A group of about twenty members were present. G. M. Eaton, of the Molybdenum Corporation of America, was elected chairman. The agreement with the above proposal was unanimous and the following committee was appointed to formulate a definite plan for the division and to enlist the support of other members of the society: *Chairman*, Dr. S. Timoshenko, Research Department, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.; *Secretary*, A. L. Kimball, Research Laboratory, General Electric Co., Schenectady, N. Y.; H. A. S. Howarth, chief engineer, Kingsbury Machine Works, Inc., Philadelphia, Pa.

All members of the Society who are interested in this scheme are asked to communicate promptly with the secretary of the above committee. Any suggestions relative to the proposed division will be gladly received.

A. L. Kimball,[1] *Secretary.*

It is a pleasure to call attention to the above announcement as it indicates a healthy growth in development of engineering and of the A.S.M.E. Attention has been called from time to time in these columns to the rapid merger of the fields of science and engineering and particularly to the increasing value of the mathematical method of analysis. The new division should do much to assist in bringing together these two great fields and to increase the usefulness of mathematics to the engineer. Registration in the division has shown a gratifying interest in it.

Charles F. Rand Dies



Charles F. Rand

Charles Frederick Rand, former chairman of the Executive Board of the Engineering Foundation, mining engineer and one of the leaders of post-war research in American industry, died on June 21, at his home, Merrywood, West Orange, N. J., at the age of 70.

Mr. Rand was identified with railway construction and the operation of iron mines in Cuba, besides being largely interested in mines of manganese and copper ores. He discovered large soft iron-ore deposits on the north coast of Cuba and built the Barraco Railroad there. He was president of the North American Exploration Co., of the Moa Bay Iron Co., and of the Antimony Corporation of New York.

In 1913 King Alfonso XIII of Spain decorated him with the Grand Cross of Knight Commander of the Order of Isabella Catolica. In 1922 he received from the French Government the Croix de Chevalier de la Legion d'Honneur for distinguished service during the World War. In 1921 he was elected an honorary member of the Iron and Steel Institute of Great Britain, in which there are but five honorary members. He was in England at that time as honorary secretary of the John Fritz Medal Board of Award to bestow the Medal for 1921 for his achievement in applied science upon Sir Robert Hatfield. Later, in Paris he bestowed the medal for 1922 upon Eugene Schneider, head of the famous Creusot Works.

Mr. Rand was a past-president of the American Society of Mining and Metallurgical Engineers, a member of the American Iron and Steel Institute, of the American Society for Testing Materials and of the National Research Council.

Mr. Rand was also Vice-President of the Welfare Federation of the Oranges and former Chairman of the Board of Directors of the American Red Cross of the Oranges. He was a member of the Engineers' Club, the Railroad Club of New York, Downtown Club, Union League, Metropolitan Club, India House and the Essex County Country Club.

He was born in Canaan, Me. On Oct. 21, 1885, he married Miss Mary E. Burnham of Milwaukee. His wife died in 1916. He is survived by a son and three daughters.

[1] Research Laboratory, General Electric Co., Schenectady, N. Y.

A Meeting on Coöperative Education

THE SECOND Annual Convention of the Association of Coöperative Colleges was held at Drexel Institute, Philadelphia, Pa., on June 23 and 24, 1927. Educators, coördinators, and representatives of industrial employers to the number of 55 registered at the convention although there are only sixteen schools and colleges offering this type of education.

Philosophy of Coöperative Training

Dr. Herman Schneider, Dean of Engineering, University of Cincinnati, opened the convention by introducing Dr. K. G. Matheson, President of Drexel Institute, who delivered the address of welcome. Dr. Matheson expressed his faith in the coöperative plan to which he was a complete convert. Philadelphia, he pointed out, was an excellent location for a school operating under such a plan, and since the adoption of the coöperative method the registration of Drexel Institute had doubled.

Joseph W. Roe,[1] read a paper on the Philosophy of the Coöperative Plan. He presented a critical analysis of the study of coöperative education recently reported in Bulletin No. 12 of the Investigation of Engineering Education carried out by the Society for the Promotion of Engineering Education, answering objections to the plan which were quoted in the report. He called attention to the fact that two-thirds of all engineering graduates ultimately go into some sort of administrative work, and also to the admission in the report that the plan had value in training men for the field of operation and administration in industrial enterprises. In closing, Professor Roe said: "That system which prepares most effectively for executive work, which trains men better to live with and work with other men, should be given free opportunity alongside of all-resident courses to develop men for this major field, i.e., the administration of those industries involving engineering operations. Such a system need not necessarily displace all older all-resident courses, but it should be given a place beside them as an essential element in engineering education."

Effect of Experience

The Effect of Experience on Classwork was the title of a paper read by James E. McDaniel.[2] He said that useful production manifested itself on classwork in six ways: (1) Practice experience prompted and gave interest, enthusiasm, and thoroughness to classwork. (2) It made a student discerning and critical of class instruction. (3) It gave the student a practical, independent, rational, and unassuming bearing on his classwork. (4) It made him retentive of class instruction. (5) From it he learned whether he had any inclination or talent for engineering. And (6) it gave him a background for a thesis.

Both of these papers brought forth considerable discussion from the floor and an interesting account by Dr. Schneider of the genesis of the idea of the coöperative plan. The meeting then adjourned and luncheon was served in the Art Gallery, Drexel Institute acting as host to the convention. Upon reassembling, Dean Fred E. Ayer[3] acted as chairman for the afternoon session.

Company Coöperation

Two papers were read, one by Dugald C. Jackson, Jr.,[4] on the Development of the Student, and the other by George W. Burns[5] on the Development of Company Coöperation. It appeared that most satisfactory response had been had from industry, and that in the entire experience of the University of Cincinnati only a negligible number of industrial relationships had been unsuccessful. It seemed to be common experience that industries felt a responsibility in the plan which extended beyond any selfish interests which they might have in training an individual directly for a specific purpose, a responsibility which they felt toward the youth of the land and the educational problem which they discharged to their ultimate advantage in coöperation with educational institutions.

Opportunity was given at the close of the discussion which followed these papers for a delightful automobile ride to Valley Forge, upon the return from which dinner was served at the Penn Athletic Club.

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Employers' Point of View

Elisha Lee[6] and Horace P. Liversidge[7] spoke on the Employer's Point of View. Portions of Mr. Lee's address follow.

I am glad indeed to have this opportunity of expressing the high opinion which I entertain for the coöperative plan of technical education. To just what extent it should supersede the older system of education in engineering subjects is a question upon which I do not care to speak authoritatively. Probably there is now and will continue to be a field for both plans. It does seem highly probable, however, that in the active affairs of this busy world there will be an increasing demand for young men whose theoretical knowledge and class-room training have been supplemented and broadened through the contacts afforded by the coöperative plan of teaching.

From the employer's viewpoint the value of any plan of technical education depends upon the degree to which it fits young men to adapt themselves rapidly to the responsibilities of their particular work, and qualify capably for supervisory and official positions. Without having personally experienced the advantages of the coöperative plan, I am strongly impressed with the belief that it can be counted upon to impart to technical training an eminently practical trend which is extremely useful in railroad work, and is becoming increasingly so with every year that passes.

The greatest problems of administering a railroad system at the present time are those of managing large masses of men and using advantageously large masses of capital.

The technical groundwork must be there, for railroading is an endless series of technical operations; but the day-to-day work of the management on a large railroad system is, first, to maintain friendly and satisfactory relations with a body of employees so numerous as literally to constitute an army, and to exercise such control over income and outgo as will assure a reasonable surplus after the payment of all expenses and charges, to the end that invested capital may receive a fair return, and the credit of the property be fully maintained as the basis of future expansion.

To cite a single example, the advantages of electrification in certain localities, under certain conditions, and for certain purposes are perfectly well understood. The problem confronting railroad management in this field is not to devise a form of electric motive power suitable for use in railroading. This has already been done. The problem is how to install electric power, where it would be superior to steam, without assuming too great a burden in the form of new capital obligations, and without too rapidly relegating to the scrap heap apparatus and facilities whose useful life is not yet ended.

The man or men who are to discharge such responsibilities adequately, and make such decisions intelligently, must know electricity from the technical viewpoint, but they must also know the uses of capital from a strictly practical business viewpoint.

In a recent extremely interesting magazine article, the writer seeks to prove that the creative minds of the world are producing new ideas far more rapidly than our civilization can assimilate them; consequently, that the world is more in need of men adapted to work of practical usefulness than of additional minds attuned to the highest forms of creative thought.

It would certainly be out of place for me to debate that point on its merits here, nor would I care to do so. I can only say that the writer advances many arguments in support of his thesis.

In my own field of work, however, I may venture to express a tentative opinion upon a somewhat parallel situation. If we take all of the operating and motive-power officials of all of the railroads of the United States and consider them as a group, we shall find that we have a considerable body of very able and experienced men, a large proportion of whom are technically trained. Concerning the general utility of their technical training and the necessity for it, I do not raise the slightest question.

I do, however, venture to throw out the suggestion that in that group of men, taken as a whole, there is probably a greater aggregate of scientific and technical knowledge than is being used, or is practically required, in the day-to-day work of railroad operation. On the other hand, it is unquestionable that that same group of men could use to better advantage in

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[5] University of Cincinnati, Cincinnati, Ohio.

[6] Vice-President, Pennsylvania Railroad, Philadelphia, Pa.

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Proposed New Division of A.S.M.E. on Applied Mechanics

WITH various branches of mechanical engineering based upon the application of the fundamentals of mechanics, physics, and mathematics, modern industry presents many problems, the solutions of which demand the application of rigorous scientific methods. The proposed new division of the A.S.M.E. on Applied Mechanics will provide a forum for the presentation and discussion of such problems, fundamental in character, in which mathematical analyses are extensively used.

The question of organizing a Professional Division on Applied Mechanics, in The American Society of Mechanical Engineers is being considered by a group of members of the Society who met during the 1926 annual meeting. This section would embrace:

I Analytical mechanics as applied to rigid, elastic, and fluid bodies, including
- (*a*) Mechanics of materials
- (*b*) Kinematics and dynamics of machines
- (*c*) Stresses in structures and machines
- (*d*) Friction and lubrication

II Physics, including
- (*a*) Heat flow
- (*b*) Thermodynamics
- (*c*) Acoustic and noise problems

III Applied mathematics

Reasons for Such Organization

Some reasons for such an organization are as follows:

1 The various branches of mechanical engineering are based upon the application of the fundamentals of mechanics, physics, and mathematics. Modern industry presents many problems whose solutions demand the application of rigorous scientific methods. Among the papers given before the A.S.M.E. are many of fundamental character in which mathematical analyses are extensively used. If the above proposed division be formed, it will offer a place for the presentation of such papers where those interested may have an opportunity to discuss them. With the present arrangement, many papers of this fundamental character are read simultaneously and it is therefore impossible to hear all of them.

2 A division on Applied Mechanics will tend to stimulate the application of analysis to the solution of engineering problems and will aid in the development of research in mechanics and technical physics, which is badly needed in this country.

3 In this country there is a large gap between mathematics and engineering. Our mathematicians do not contribute much toward the solution of technical problems, and on the other hand, our engineers prefer to use empirical formulas instead of having recourse to more thorough analyses. Closer coöperation between pure and applied sciences will undoubtedly be beneficial to both branches of knowledge. The organization of a division on Applied Mechanics will undoubtedly bring about a better contact between experts in mathematics and in engineering. Furthermore, there is no division of our Society, nor any association in the United States, that is now devoted to this field.

4 The proposed division on Applied Mechanics will offer a means whereby engineers in this country can make contact with similar foreign organizations. The Third International Congress in Applied Mathematics and Mechanics that was held in Zurich in September, 1926, attracted a large number of scientists and engineers from all parts of the world. Only four representatives from the United States, however, attended this congress. This is a poor representation from this country in proportion to the importance of our educational institutions and to the magnitude of our industries. This small attendance can be explained by a lack of organization of those interested in applied science which the above division will undoubtedly provide.

Committee Appointed to Make Plan for Division

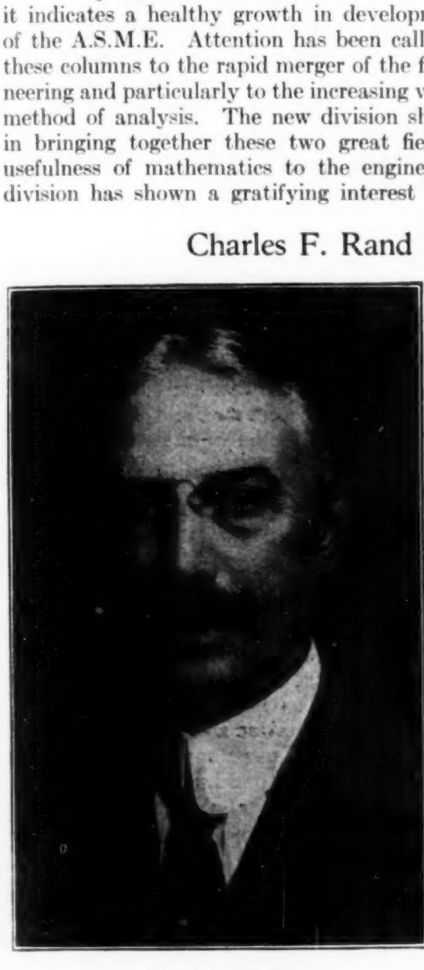
According to the announcement at the annual convention at New York, a meeting was held on December 8, in the Society's rooms to discuss the formation of such a new professional division. A group of about twenty members were present. G. M. Eaton, of the Molybdenum Corporation of America, was elected chairman. The agreement with the above proposal was unanimous and the following committee was appointed to formulate a definite plan for the division and to enlist the support of other members of the society: *Chairman*, Dr. S. Timoshenko, Research Department, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.; *Secretary*, A. L. Kimball, Research Laboratory, General Electric Co., Schenectady, N. Y.; H. A. S. Howarth, chief engineer, Kingsbury Machine Works, Inc., Philadelphia, Pa.

All members of the Society who are interested in this scheme are asked to communicate promptly with the secretary of the above committee. Any suggestions relative to the proposed division will be gladly received.

A. L. Kimball,[1] *Secretary.*

It is a pleasure to call attention to the above announcement as it indicates a healthy growth in development of engineering and of the A.S.M.E. Attention has been called from time to time in these columns to the rapid merger of the fields of science and engineering and particularly to the increasing value of the mathematical method of analysis. The new division should do much to assist in bringing together these two great fields and to increase the usefulness of mathematics to the engineer. Registration in the division has shown a gratifying interest in it.

Charles F. Rand Dies



Charles F. Rand

CHARLES Frederick Rand, former chairman of the Executive Board of the Engineering Foundation, mining engineer and one of the leaders of post-war research in American industry, died on June 21, at his home, Merrywood, West Orange, N. J., at the age of 70.

Mr. Rand was identified with railway construction and the operation of iron mines in Cuba, besides being largely interested in mines of manganese and copper ores. He discovered large soft iron-ore deposits on the north coast of Cuba and built the Barraco Railroad there. He was president of the North American Exploration Co., of the Moa Bay Iron Co., and of the Antimony Corporation of New York.

In 1913 King Alfonso XIII of Spain decorated him with the Grand Cross of Knight Commander of the Order of Isabella Catolica. In 1922 he received from the French Government the Croix de Chevalier de la Legion d'Honneur for distinguished service during the World War. In 1921 he was elected an honorary member of the Iron and Steel Institute of Great Britain, in which there are but five honorary members. He was in England at that time as honorary secretary of the John Fritz Medal Board of Award to bestow the Medal for 1921 for his achievement in applied science upon Sir Robert Hatfield. Later, in Paris he bestowed the medal for 1922 upon Eugene Schneider, head of the famous Creusot Works.

Mr. Rand was a past-president of the American Society of Mining and Metallurgical Engineers, a member of the American Iron and Steel Institute, of the American Society for Testing Materials and of the National Research Council.

Mr. Rand was also Vice-President of the Welfare Federation of the Oranges and former Chairman of the Board of Directors of the American Red Cross of the Oranges. He was a member of the Engineers' Club, the Railroad Club of New York, Downtown Club, Union League, Metropolitan Club, India House and the Essex County Country Club.

He was born in Canaan, Me. On Oct. 21, 1885, he married Miss Mary E. Burnham of Milwaukee. His wife died in 1916. He is survived by a son and three daughters.

[1] Research Laboratory, General Electric Co., Schenectady, N. Y.

A Meeting on Coöperative Education

THE SECOND Annual Convention of the Association of Coöperative Colleges was held at Drexel Institute, Philadelphia, Pa., on June 23 and 24, 1927. Educators, coördinators, and representatives of industrial employers to the number of 55 registered at the convention although there are only sixteen schools and colleges offering this type of education.

Philosophy of Coöperative Training

Dr. Herman Schneider, Dean of Engineering, University of Cincinnati, opened the convention by introducing Dr. K. G. Matheson, President of Drexel Institute, who delivered the address of welcome. Dr. Matheson expressed his faith in the coöperative plan to which he was a complete convert. Philadelphia, he pointed out, was an excellent location for a school operating under such a plan, and since the adoption of the coöperative method the registration of Drexel Institute had doubled.

Joseph W. Roe,[1] read a paper on the Philosophy of the Coöperative Plan. He presented a critical analysis of the study of coöperative education recently reported in Bulletin No. 12 of the Investigation of Engineering Education carried out by the Society for the Promotion of Engineering Education, answering objections to the plan which were quoted in the report. He called attention to the fact that two-thirds of all engineering graduates ultimately go into some sort of administrative work, and also to the admission in the report that the plan had value in training men for the field of operation and administration in industrial enterprises. In closing, Professor Roe said: "That system which prepares most effectively for executive work, which trains men better to live with and work with other men, should be given free opportunity alongside of all-resident courses to develop men for this major field, i.e., the administration of those industries involving engineering operations. Such a system need not necessarily displace all older all-resident courses, but it should be given a place beside them as an essential element in engineering education."

Effect of Experience

The Effect of Experience on Classwork was the title of a paper read by James E. McDaniel.[2] He said that useful production manifested itself on classwork in six ways: (1) Practice experience prompted and gave interest, enthusiasm, and thoroughness to classwork. (2) It made a student discerning and critical of class instruction. (3) It gave the student a practical, independent, rational, and unassuming bearing on his classwork. (4) It made him retentive of class instruction. (5) From it he learned whether he had any inclination or talent for engineering. And (6) it gave him a background for a thesis.

Both of these papers brought forth considerable discussion from the floor and an interesting account by Dr. Schneider of the genesis of the idea of the coöperative plan. The meeting then adjourned and luncheon was served in the Art Gallery, Drexel Institute acting as host to the convention. Upon reassembling, Dean Fred E. Ayer[3] acted as chairman for the afternoon session.

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their daily work a greater volume of economic and business knowledge and experience; and in fact there is not a member of that group, deserving to be classed as a useful officer, who is not constantly endeavoring by every means to increase the scope of his learning and experience, and the breadth of his viewpoint, in those directions.

In the light of such reflections as these, I feel, can be discerned our highest reasons for turning hopefully to the coöperatively trained mechanical graduate entering railroad work. If he has applied himself and grasped and used the opportunities open to him outside the class room, we should be able to welcome him as bringing to railroad work a new and needed form of trained usefulness.

He will have had the indespensable lessons of the class room and text book, but he will also have had what neither of these alone can give—a practical close-range insight into the working of some business or enterprise which day in and day out must produce a surplus of income over outgo, or cease to function.

In other words, he will have had at least the beginning of that contact with the real affairs of life, and of that practical education in the commerical significance and relations of technology, which the average graduate, not coöperatively educated, only begins to acquire after he starts to forget some of the lessons learned within the college walls.

As this world is organized, there seems to be room for only a limited number of people who can devote their lives to the advancement of pure science or the pursuit of abstract knowledge in any department of thought. Moreover, in the present state of knowledge that small number can easily keep the rest of us busy trying to catch up with them.

On the other hand, it is a certainty that there is almost unlimited need for men trained in the straight thinking which only intimate contact with science can give, but whose object in life is not so much the furtherance of abstract learning and pure discovery as it is the practical application of established knowledge to the material needs and progress of the human race.

For the production of useful men of this kind, the coöperative plan of technical education seems highly adapted and particularly so in this happy country of ours whose people are using to better advantage than those of any other nation the forces and principles which pure science and discovery have revealed.

Thesis-Degree Problem

The program of the second day was devoted to the thesis-degree problem and to a business meeting. W. H. Timbie[8] spoke of the policy inaugurated at M.I.T. of excusing from the more elementary routine of class-room and laboratory work and from required attendance at classes a group of honor men chosen by their instructors on a basis of their record and achievement. Mention of this policy was made in the October, 1925, issue of this journal. Dr. Schneider spoke of continuous theses worked out at University of Cincinnati, juniors being assigned to assist seniors in the routine of thesis work and taking charge of it when reaching their senior year. In this way an extensive subject could be continuously investigated.

David B. Porter[9] read a paper on Scheduling Theses by the Gantt Chart, a method employed by him for keeping in touch with the progress of thesis work done by men working under him and having the advantage of establishing for the student a definite schedule of accomplishment.

The officers of the Association, who were reëlected, are Dr. Herman Schneider, president, Dr. K. G. Matheson, vice-president, and C. W. Lytle,[10] secretary-treasurer.

Book Reviews and Library Notes

The Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Books Received in the Library

Care and Operation of Machine Tools. By J. W. Barritt. John Wiley & Sons, New York, 1927. Cloth, 6 × 9 in., 292 pp., illus., $2.75.

Contents: Lubrication; Emery wheel; Drill press; Shaper; Vertical boring mill; Lathe; Planer; Horizontal boring mill; Milling machine; Index.

The author explains the construction of the various parts of machine tools, explains why and where adjustments are necessary, tells how to make them, gives directions for operating the different mechanisms properly and calls attention to the precautions necessary for accuracy, speed, and neatness. The text is simple and explicit, suitable for use by apprentices and trade-school students and for individual study.

Fatigue of Metals; with chapters on the Fatigue of Wood and Concrete. By H. F. Moore and J. B. Kommers. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 326 pp., illus., diagrams, tables, $4.00.

The aim of this book is to present the important results of experimental investigations of the strength of metals under repeated stress, to review current theories of fatigue of metals, and to describe the apparatus and methods used in studying the subject experimentally. The authors have been actively engaged in investigation of the subject and have also drawn on the work of other American and foreign investigators, with the result that their book is a useful review of present knowledge. A good bibliography is included. In addition to the main subject, wood and concrete are discussed and the scanty data which are available on these subjects are given.

Fourth Power Kink Book. Compiled by Editorial Staff of *Power*. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 232 pp., illus., $1.50.

The editors of *Power* have selected the contents of this book from the articles contributed to that magazine by men in charge of the operation and repair of power-plant machinery. These articles describe original ways of making unusual repairs, "short cuts" and labor-saving devices which have been used successfully by practical men.

House Heating with Oil Fuel. By P. E. Fansler. Third edition. Heating and Ventilating Magazine Co., New York, 1927. Cloth, 7 × 10 in., 354 pp., illus., map, $4.

A comprehensive survey of the use of oil for domestic heating, written in non-technical style and intended for use by contractors, engineers, and purchasers of equipment for burning oil. The various fuel oils are described, combustion is explained and the various types of boilers and burners are described. Accessories, storage, house insulation, safety measures, and similar topics are discussed practically, and much useful general information is given.

Inventions and Patents, Their Development and Promotion. By Milton Wright. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 8 in., 225 pp., $2.50.

A plainly written book of practical advice for inventors and

[8] Massachusetts Institute of Technology, Cambridge, Mass.

[9] Asst-Prof. Industrial Engineering, New York University, New York, N. Y. Mem. A.S.M.E.

[10] Director of Industrial Coöperation, New York University, New York, N. Y. Mem. A.S.M.E.

would-be inventors. Tells how to obtain a patent and how to market it. Warns the inventor of various dangers in his path.

Lectures on Dielectric Theory and Insulation. By J. B. Whitehead. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 154 pp., diagrams, tables, $2.50.

Professor Whitehead's book reviews the salient features of dielectrics for which the classical theory fails to account, reviews the literature describing experimental research upon the behavior of dielectrics and coördinates it with fundamental theory as fully as possible and indicates some directions in which further experimentation may be fruitful. The treatment is very condensed. The text is in the form of nine lectures, prepared for delivery in France as an exchange professor, which summarize the course given by the author to advanced students at the Johns Hopkins University. A bibliography is included.

Logic of Modern Physics. By P. W. Bridgman. Macmillan Company, New York, 1927. Cloth, 6 × 9 in., 228 pp., $2.50.

Many of the new facts discovered in recent years in the domain of relativity and quantum theory have necessitated such complicated modifications in our notions of the fundamental concepts of physics that it has become a matter of the first importance to review those concepts in inclusive fashion. This task Professor Bridgman essays in the present volume. He examines critically the various concepts, in the light of experimental knowledge, with the purpose of leading to a clearer understanding of what the ideals of physics should be and of what the present structure of physics is.

Machine Design, Construction and Drawing. By Henry J. Spooner. Sixth edition. Longmans, Green & Co., London and New York, 1927. Cloth, 6 × 9 in., 775 pp., illus., diagrams, $7.

An English textbook which begins with instruction in mechanical drawing, and then proceeds to treat with fullness machine parts, fastenings, bearings, gearing, etc. An unusual amount of practical information is given.

Mathematics of Engineering. By Ralph E. Rost. Williams & Wilkins Co., Baltimore, 1927. Cloth, 6 × 9 in., 540 pp., $7.50.

The author who is professor of mathematics in the Postgraduate School of the U. S. Naval Academy has prepared this book primarily for the student officers who are to specialize in mechanical, civil, electrical, aeronautical, or radio engineering, in aerology, in naval construction, or in ordnance engineering. The result is a convenient introduction to mathematics with special attention to the requirements of the engineer, intended for students of maturity who already are somewhat familiar with conventional courses in mathematics.

Metallurgy; a general treatise for the use of students of engineering. By Henry Wysor. Third edition. Chemical Publishing Co., Easton, Pa., 1927. Cloth, 6 × 9 in., 433 pp., illus., $6.

In preparing this elementary textbook, the author has had in mind not only those students who intend to become producers of metals but also those who will become responsible for their selection and fabrication. His book therefore aims to concentrate attention upon the properties of the various metals and upon the mechanical and thermal operations by which these properties are developed and utilized.

Beginning with descriptions of the raw materials, their preparation, and of metallurgical furnaces, the extraction and refining of the various metals are explained. Chapters are then devoted to general matters, such as alloys, casting, working, and heat treatment. The text is concise and clear.

Modern Industry. By Ernest L. Bogart and Charles E. Landon. Longmans, Green & Co., New York, 1927. Cloth, 6 × 9 in., 593 pp., illus., maps, $3.75.

The authors of this work, believing that an understanding of industry precedes an understanding of business, have filled a gap that they believe exists in our economic textbooks, by this volume, which is intended as a background to the study of economics.

Starting with a description of the characteristics of modern industry, the book discusses successively man as a contributing agent and nature as a conditioning factor. Typical great agricultural and manufacturing industries are then studied, to make clear the principles underlying modern industry and the methods followed in producing wealth. Finally, processes of exchange are considered.

The book is descriptive, not theoretical. It gives a clear, interesting account of industry as a whole, in which the relations of the different parts to each other are brought out. Excellent lists of references are given.

Principles of Employment Psychology. By Harold Ernest Burtt. Houghton Mifflin Co., Boston and New York, 1926. Cloth, 6 × 9 in., 568 pp., $4.

This book, says its author, "is an outgrowth, in the first instance, of material used for several years in presenting principles of employment psychology to college students, and in the second instance, of practical experience in personnel work and frequent contact with business men interested in psychology in so far as it relates to their problems. Effort is made, on the one hand, to give a fairly comprehensive account of the principles involved for the use of students preparing for practical psychological work in industry, and on the other hand, to avoid a discussion that is too technical for the reader without a psychological background." An extensive bibliography is given.

Principles of Refrigeration. By William H. Motz. Nickerson & Collins Co., Chicago, 1926. Cloth, 6 × 9 in., 657 pp., illus., diagrams, tables, $5.

The substance of this book has been used for three years by the National Association of Practical Refrigerating Engineers as a course of lectures to its chapters and for home study. It aims to give, without using higher mathematics, a comprehensive grounding in the fundamental principles of refrigeration and a description of their application to ice making and refrigeration. It describes the construction of ice and refrigerating plants and the operation and care of the apparatus, and gives much practical information of value to those employed in the industry.

Psychology of Selecting Men. By Donald A. Laird. Second edition. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 345 pp., illus., charts, $4.

This book is the work of a trained psychologist who has attempted to supply a technical account in a non-technical way, of the fundamental considerations in selecting men. Dr. Laird first surveys critically the traditional methods of selection, by letter, by interview, by photograph, etc. The latter portion of the book describes the scientific methods of selection and discusses the use and limitations of psychological and intelligence tests. This edition contains new chapters which point the way for the utilization of definite tests in choosing employees.

Slide Valves and Valve Gearing. By Peter Youngson. James Munro & Co., Glasgow, 1927. Cloth, 8 × 10 in., 233 pp., illus., diagrams, 12s 6d.

A clearly written, profusely illustrated textbook on the working and management of steam valve gear, intended especially for marine engineers. The author is the head of the marine engineering department, Central Municipal Technical School, Liverpool.

Statics and the Dynamics of a Particle. By William Duncan MacMillan. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 430 pp., $5.

A discussion of the general theory, intended particularly for students of astronomy, physics, or mathematics, but also of interest to engineers who wish further knowledge than that necessary for ordinary applications. The text begins with the fundamental concepts and postulates and covers the subjects usually taught in colleges. A knowledge of calculus is necessary.

Statistical Mechanics with Applications to Physics and Chemistry. By Richard C. Tolman, Chemical Catalog Co., New York, 1927. (American Chemical Society. Monograph Series.) Cloth, 6 × 9 in. 334 pp., $7.

Statistical mechanics offers to the chemist and physicist a powerful method, wide in scope, for attacking theoretical problems. Those engaged in the study of the behavior of atoms and molecules will find this book useful, for it develops the theory of statistical mechanics in logical fashion and shows how the science may be applied to the elucidation of a number of chemical and physical phenomena.

Technische Schwingungslehre, bd. 2; Schwingungen im Maschinenanlagen. By L. Zipperer. Walter de Gruyter & Co., Berlin and Leipzig, 1927. Cloth, 4 × 6 in., 124 pp., illus., 1.50 r.m.

After the discussion of vibration in general given in the first volume of the work, the second proceeds to discuss the individual methods for calculating the specific rate of torsional vibration in shafts with various numbers of disk flywheels. The method of calculating transverse vibrations is then given. Attention is then turned to experimental methods and to methods for avoiding vibration.

Die Trockentechnik. By M. Hirsch. Julius Springer, Berlin, 1927. Cloth, 6 × 9 in., 366 pp., illus., diagrams, plates in pocket, 31.80 r.m.

This new addition to the literature upon drying is of especial value for its thorough discussion of the scientific principles involved and for the numerical data that it provides the designer of drying processes.

The book is divided into two sections. In the first the author discusses the general physical principles of artificial drying, the heat balance of evaporation and of drying, the efficiency of drying, the graphic presentation of the condition of damp gases and materials, interchange between damp gases and materials, data for the design of processes, the design of air-drying processes, the design of drying processes by heat transfer through heated surfaces, and the calculation of the energy consumed. The second section discusses practice. The various methods are discussed, the machinery is described, and the use of the methods for drying many materials is explained.

Verhalten von Raschlaufenden Gegendruckturbinen bei Drehzähl-Änderungen. By Kurt Mauritz. R. Oldenbourg, Munich and Berlin, 1927. Paper, 8 × 11 in., 42 pp., illus., diagrams, 4.50 r.m.

The use of the steam turbine as a marine engine and a locomotive has created new problems for the builder of these machines. In addition to the question of condensation, there comes into prominence the influence of great variations in speed upon the power, torque, and efficiency of the engine. Upon these points, the author states, there have been until now few investigations which are of help to the builder. He has therefore undertaken an investigation of the influence of the speed of revolution and endeavored to derive from his findings a method for calculating this influence in advance. This report describes his tests in detail and gives his conclusions.

Versuche über das Ziehen von Hohlkörpern. By Martin Sommer. V.D.I. Verlag, Berlin, 1926. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft. 286.) Paper, 8 × 11 in., 94 pp., illus., diagrams, tables, 7.50 r.m.

The purpose of this investigation was the discovery of a method by which the power required for stamping hollow articles of sheet metal and the depth attainable could be determined from the strength of the metal. Equations were developed, tested, and found to be sufficiently accurate for practical purposes. An example of the application of the method is included.

Water Power Engineering. By H. K. Barrows. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 734 pp., illus., diagrams, tables, $6.

Intended primarily as a text for use in courses given at the Massachusetts Institute of Technology, this book discusses the applications of hydrology, hydraulics, and mechanics involved in the design of water-power plants and the electric transmission of power. Starting with a review of the distribution of water power and its use throughout the world, the book discusses hydrology, the study of stream-flow data, turbines, plant arrangement, dams, canals, power-house equipment, regulation, transmission, costs, reports, etc. Much practical information is brought together in convenient form.

Zeitstudien bei Einzelfertigung. By Hans Kummer. Julius Springer, Berlin, 1926. Paper, 6 × 9 in., 113 pp., diagrams, 9.60 r.m.

Most of the literature upon time studies, says this author, is devoted to studies of the time required for producing machine parts manufactured in large numbers or in series. In the present book he discusses the application of time studies to operations that occur infrequently and to the making of single parts of machines.

National American Standard for Fire-Hose-Coupling Screw Threads

(Continued from page 925)

In May of this year the legislature of Maryland passed a similar bill making it a misdemeanor for anyone to purchase or sell fire-hose couplings, fire hydrants, and other fire-fighting apparatus which is not equipped with the National American Standard $2^1/_2$-inch Fire-Hose Coupling Screw Thread. The state of Oregon was the first to pass a law on this subject and it was later followed by the State of Massachusetts. Other states, however, have accomplished the same result by encouraging the protected cities and towns to convert their equipment without the impetus of state compulsory legislation. During the calendar year of 1926, for instance, 566 protected cities and towns of this country completed the conversion of their fire-fighting equipment from the local standard to the National American Standard.

This means that since 1920 when the National Board of Fire Underwriters undertook the task of promulgating this standard, and up to the end of the calendar year 1926, a total of 2238 protected cities and towns have adopted the National American Standard, having resized their equipment and arranged for the careful gaging of all new equipment. As a result of this activity approximately 40 per cent of the total number of protected cities and towns in the United States have adopted and put into use the National American Standard. Twenty-five of the cities included in this group have a population of more than 100,000. At the present time in 24 states the conversion process is now well organized and progressing satisfactorily. Already in Oregon and Tennessee this work of conversion is practically complete.

The official adoption of the national standard and the resizing of existing equipment will not insure for all time the going together of the fire-hose fittings of the towns and cities of any community. This can only be accomplished by eternal vigilance which begins with a careful inspection of all the threads of each and every new lot of fire hose and fire hydrants as they are delivered. It is perfectly obvious also that this inspection must be more than a casual examination of the threads and the screwing on of an old mating part to the new coupling or nipple. It is conceivable that such a procedure might accept new fire hose or fire hydrants which would not mate with one-half of the fire department's equipment.

Old couplings, hydrant nipples, or cast-iron hydrant caps are not reliable as test pieces or specimens, owing to wear and corrosion. Modern manufacturing processes call for the use of hardened steel models or final inspection gages by the manufacturers, and hardened steel models or field inspection gages by the persons responsible for accepting the equipment. It was not, however, until the nation-wide standardization program gained its present headway that the production of these hardened steel gages became economically possible.

A set of standard field-inspection gages consists of six pieces, three to gage the coupling or internal thread and three to gage the nipple or external thread. The first three consist of a "Go" plug thread gage, a "Not-Go" plug thread gage, and a "Not-Go" plug plain cylindrical gage. The second group consists of a "Go" ring thread gage, a "Not-Go" ring thread gage, and a "Not-Go" ring plain cylindrical gage. All six of these gages should be non-adjustable. When applied to the threaded parts of a coupling the "Go" thread gages, both plug and ring, insure that all parts which pass this inspection will go together and will never be too tight. This test consists in screwing the gages on the parts being tested, covering the full length of the thread. The "Not-Go" thread gages, on the other hand, are used to make sure that the parts will not produce a joint which is too loose. These gages should jam at about the second thread. The "Not-Go" plug and ring plain cylindrical gages check the height of the thread, which means the depth of engagement:

A pamphlet describing this standard known as "B 26-1924" may be secured on application to the Society's Publication-Sales Department, together with two explanatory pamphlets entitled "Production of National (American) Standard Fire-Hose Coupling Screw Thread" and "Field Inspection of National (American) Standard Fire-Hose Coupling Screw Thread."